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HYDRAULIC RAMS

THEIR

PRINCIPLES AND CONSTRUCTION

A HANDBOOK FOR PRACTICAL MEN

BY

J. WRIGHT CLARKE

AUTHOR OF 'TABLES FOR PLUMBERS' 'SCIENCE FOR PLUMBERS'
'PLUMBING PRACTICE' 'PUMPS' ETC.

SECOND EDITION, REVISED AND ENLARGED

WITH 41 ILLUSTRATIONS
RE-DRAWN FOR THIS EDITION

LONDON
B. T. BATSFORD, 94 HIGH HOLBORN
1907

PREFACE

TO THE SECOND EDITION

As the first edition of this book has been exhausted, and the work is still in demand, the issue of a second edition has been decided upon.

Advantage has been taken of the new issue to rewrite the greater portion of the text, to reset the subject-matter and divide it into chapters for convenience of reference.

The whole of the old illustrations have without exception been re-drawn, and other examples added to suit the improved character of the new book.

The Author trusts the information given in the following pages will be found useful to those who have to deal with problems in the construction and fixing of hydraulic rams. He also hopes that his efforts to impart such knowledge will be accorded the same kind appreciation as has been so generously bestowed on his other volumes on various branches of plumbing and sanitary work.

J. WRIGHT CLARKE.

LONDON: *September* 1907.

CONTENTS

HYDRAULIC RAMS

CHAPTER I

DESCRIPTION

A HYDRAULIC ram is a self-contained machine made of cast-iron, and consisting of a body-pipe, a dash-valve, a delivery-valve, an air-valve, and an air-vessel or chamber.

USE

The machine is used for raising water from a low level, such as a valley, to a high level, such as a tank in a house, or to a reservoir for supplying water to a house or other building.

As its name implies, a hydraulic ram is worked by the power of water. Some of the water which works it is forced to the higher level, the remainder running to waste, or, where circumstances permit and it is advantageous to do so, to a low-level stream or reservoir where it can be utilised for other purposes.

Before describing a ram and its capabilities it will be necessary to explain a few principles in connection with hydro-mechanics. Otherwise the action of a ram will be difficult to understand.

THE POWER OF MOVING WATER

There are but few people who, when paying a visit to a seaside resort, have not noticed how the waves of an incoming tide dash against a sea-wall, or on to a rocky shore, with such violence as to make loud noises and throw the sea-water spray into the air to a considerable height. The water then recedes from the shore, but again returns as a wave and is again thrown up into the air. This, what may be termed "oscillating" motion of the tide, is continuous until high tide has been reached. The motion then gradually ceases as the tide falls.

There are also many people, including plumbers, who have heard a peculiar knocking noise in a service-pipe after a quantity of water has been drawn and the draw-off tap has been suddenly closed.

In each case the noise is made by the water knocking against a hard substance, a sea-wall in one case and the inside of a pipe in the other case. When the water is simply resting against the wall or the sides of a pipe, as the case may be, no noise is heard. To cause the sound motion must be imparted to the water, and it is in the act of arresting the motion of the water that sound is caused.

If the sea-wall or the sides of the pipe are not strong enough to resist the force of the impact of the water, the former would be pushed over or broken up, and the latter would have its sides pushed out and torn or broken.

If, instead of the waves dashing against a solid sea-wall, they were projected into a low cavern

on a rock-bound seashore, and the cavern had a skyward opening through the roof, the force of the incoming waves would cause some of the sea spray to be thrown through the roof to a height much above the level of the sea. The swifter the velocity of flow of the waves, the higher the water is ejected through the opening in the roof of the cavern. For a similar reason, wherever a sewer empties into the sea, the discharging end has to be provided with a means of preventing the waves rushing up the sewer.

Under certain conditions an almost similar action takes place in a service-pipe as in a cavern, excepting that the water is confined in a tube instead of in a chamber of a lesser uniform character.

Let A, Fig. 1, represent a cistern to hold water, and B, a service-pipe leading to the cock C. If the cock is opened to allow water to flow out, and is then suddenly closed, a knocking noise would be heard near the cock ; and if the pipe was a thin or weak one, it would be burst near the cock by the force of the shock.

Assume that the pipe B is continued beyond the cock C, and is turned upwards, as shown by the double dotted lines D. The water will stand in the pipe D up to the same level as the surface of the water in the cistern A. If the cock C is opened, water will be drawn from the pipe D and also from the cistern A. Although water is drawn from the two directions, the pipe D will be nearly emptied, because there is nothing to support the contained water. But when the cock is quickly closed the water coming from the cistern will attain such a momentum that it will rush up the pipe D, and if

the top end of the pipe is not at a higher level than the cistern, water will be projected from the top and open end of the pipe. When the motion of the water has subsided, the pipe will again fill up to its original level.

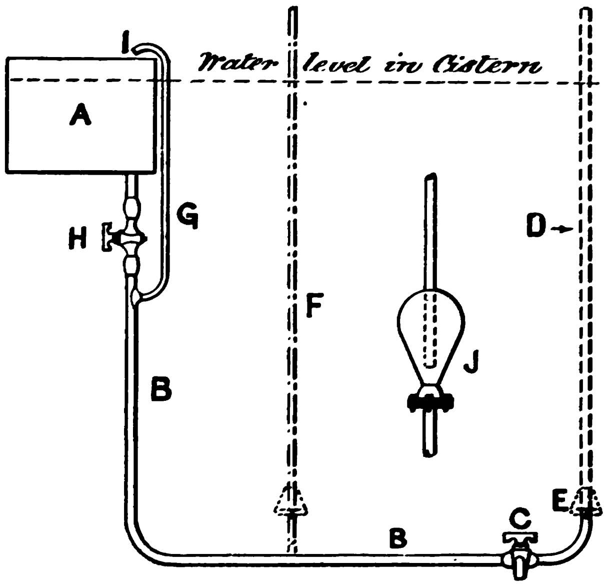

FIG. 1.

If a valve which opens upwards only is fixed in the pipe D, at the position shown at E, the water will still rise in the pipe to the same level as that in the cistern, but on opening the cock C the whole of the escaping water will come from the cistern. On quickly closing the cock C, the

momentum obtained by the water in the pipe B, instead of knocking against the end of the pipe, as in the first instance, will knock against the underside of the valve E. The valve will be pushed open for a short distance by the shock and a small quantity of water will be forced through into the pipe above.

By constantly opening the cock C, allowing the flow of escaping water to attain its maximum velocity, and then quickly closing the cock, more water will be injected into the pipe D. If the action is repeated a number of times the pipe D will be filled, even if it is continued ten or, in some cases, twenty times the height of the cistern above the tap C.

The pipe D need not necessarily be in the position shown in the drawing. If it were fixed in the manner indicated by the double dot-and-dash lines at F the same results would be obtained. The water, however, would not be raised to the same height as in D, because of the shorter distance between the pipe F and the cistern. This signifies that the weight and volume of moving water acting upon the pipe F is less than on D.

The foregoing reasoning applies to the air-vent pipe, G. This pipe is for the admission of air into the pipe B, to allow it to run empty when the stop-cock H is closed for any purpose. When the draw-off cock C is suddenly closed after drawing water from it, a small quantity will be ejected out of the open end, I, of the vent-pipe. For this reason it is always necessary to turn the end of the pipe over the cistern edge, or to continue it for some height above the cistern.

Take another illustration :—Let Fig. 2 be a

cistern with a draw-off cock and pipe fixed as shown. At the end of the pipe a fountain-jet is fixed. The water will play out of the jet to a height nearly level with the surface of the water in the cistern. Immediately the draw-off tap is opened the height to which the jet was playing will be lowered. On quickly closing the cock, however, the jet will, for a brief period of time, play to a

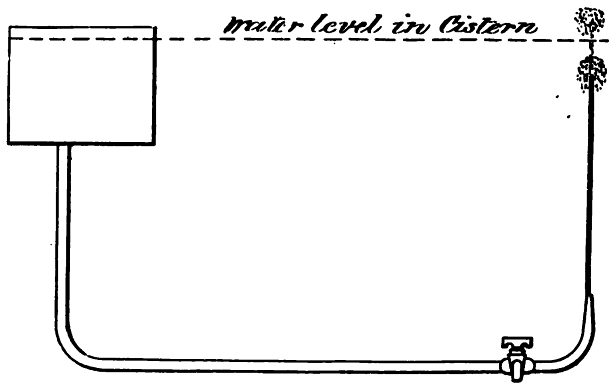

FIG. 2.

height much above the level of the surface of the cistern water; but as soon as the momentum of the water has been overcome, the fountain will play to the same height only that it did in the first instance.

The foregoing illustrations show that moving water exerts considerable force against anything which is placed in its path. In all the cases that have been cited it was the force of terrestrial gravity which put the water in motion. In the case of sea

waves, however, the wind in some instances has an influence upon their flow. Water, like all other inanimate matter, has no power of itself to move or to stop when put into motion. To stop the motion of any kind of matter an opposing force has to be brought into action.

The contents of the two vertical pipes B and D, Fig. 1, when at rest are in a state of equilibrium. When the water in B is in motion, its weight, *plus* its impetus, is in excess of the dead weight only of the water contained in D. Hence, under the conditions given above, the momentum of the water in B causes some to be forced through the valve E into the pipe D, although the weight of the contents of the latter pipe offers considerable resistance.

The power that projects the sea water through the roof of a cavern, or which bursts a water-pipe and forces water through another pipe or through a fountain jet, as illustrated by Figs. 1 and 2, is the same kind of power that causes a ram to raise water to a height much above itself. A hydraulic ram is only an automatic acting appliance for controlling and applying that power in an especial manner so as to obtain an end or object.

USE OF AN AIR-VESSEL

Again referring to Fig. 1, each time the cock is opened and then quickly closed a small quantity of water is forced through the valve E. To enable this small quantity to pass through the valve, the water in the pipe above it must be pushed upwards. This water is in a state of inertia, and to put it into motion a certain amount of force must be exerted. Consequently the force exerted by the

momentum of the water when flowing through the pipe B is split up, part of the force being utilised in driving the water through the valve E, and part in putting the water above E into motion.

If the water above the valve E was kept in motion between the times of opening and shutting the cock C, the force expended in overcoming the inertia of the water above E would be utilised in forcing a larger quantity through the latter valve. Not only would the available force be better utilised, but there would also be less shock or jar and noise made by the flowing water knocking against the underside of the valve E. The bursting strain exerted inside the pipe D would also be less.

The reduction of the bursting strain inside D; the lowering of the noise made by the water knocking against the valve E; the forcing of a larger quantity of water through the latter valve; and the constant upward motion of the water in D, in the intervals between opening and shutting the cock C, are all obtained by fixing an air-vessel over the valve E, as shown by the small drawing J, Fig. 1. The use of the air-vessel will be further dealt with in a future Chapter.

CHAPTER II

On Energy and Friction

References have already been made as to loss of power by friction and other causes.

Although usually looked upon as 'loss,' there is no such thing in Nature as waste of any kind. The only loss is in that the whole of the energy which may be exerted does not produce results in the desired direction.

In the working of a hydraulic ram only a percentage of the water used is sent up to the storage tank or reservoir. When entering into the ram the water contains a certain amount of energy which bears some proportion to the height whence it has fallen before it enters the appliance. The greater volume of the water runs to waste, but before doing so it has parted with the greater part of the energy which it contained when entering the ram.

The escaping water is not wasted. It is still available for use in Nature's economy. It may evaporate, form clouds, and as rain again contribute to the store whence it was drawn to supply the ram; or it may flow into a brook or stream and eventually be discharged into the sea. Again, growing vegetation may absorb some of it, or a portion may soak into the ground and find its

way into a well from which it can be pumped for use.

None of the energy absorbed by the water before it enters a ram is wasted. On the contrary, it is utilised to the utmost. The greater portion is used in forcing some of the water to a level much higher than the ram. Other portions of the energy are exercised in opening and closing the valves inside the appliance. Considerable energy has to be exerted intermittently to cause the water in the drive-pipe to flow in a backward and upward direction. If the water does not thus reflow, the ram will cease to work. Hence, the so-called loss of energy is only apparent. Indeed the hidden energy is actually a necessity for the efficient working of the appliance.

From another point of view, energy may be looked upon as being heat. The temperature of the water in the delivery-pipe from a hydraulic ram is always higher than the water in the entering end of the drive-pipe.

In machinery some of the working parts are worn away by reason of their rubbing together, and lubricants are used to reduce the power thus lost by friction. But lubricants cannot be used for reducing the friction of water when it is passing through tubes or pipes. Hence, the latter should be made as smooth inside as possible, so that the water may glide through them without forming eddies or cross-currents, or violently disturbing the relative positions of the molecules of the water.

The friction of water when passing through pipes or tubes increases directly as the square of the velocity of flow; so that by using large size

pipes for delivering a given quantity of water in a given time, the loss of energy absorbed by friction is much reduced.

Pipes that are rough or with projections inside, or having very sharp bends or elbows at every change of direction, absorb so much energy that a lesser quantity of water will pass through them than would be the case if they were smoother inside and had bends made to large radii. This applies to pipes used in connection with hydraulic rams, whether viewed from the actual efficiency of the appliance itself, or from the amount of energy that can first be imparted to the working water and then be abstracted from it in the form of work or duty done.

In the engineering profession one of the many problems that the members have to deal with is to reduce loss of energy by friction in its many forms. They have also to devote quite as much thought to the development of friction and make it a useful servant. A simple example of this may be referred to:—The journals or bearings in which iron shafting is revolving are oiled to reduce the friction between the parts in contact; but the pulleys fixed on the shafting are sanded or have resin dust sprinkled on them; otherwise the belting would 'slip' instead of causing the pulleys and shafting to turn as may be desired.

Water wheels would not be turned by the water that passes either under or over them if the perimeters of the wheels were not roughened by 'floats' or 'buckets' for the water to impinge against or load by its weight.

If there were no resistance offered by friction when water is passing through the delivery-valve

and pipe of a hydraulic ram the appliance would cease to work, because the water would not intermittently reflow in the drive-pipe. The latter pipe however, must be fairly smooth inside, otherwise the backward flow of the drive water would be too much retarded by friction.

Having dealt with the elements of science so far as it is applicable to the hydraulic ram, the form and action of that appliance will now be considered.

CHAPTER III

FORM OF HYDRAULIC RAM

WITHOUT troubling the reader or student to wade through a history of these appliances from the time of their introduction up to now, one only is here introduced. The reason for its selection is because it is suitable for a diagrammatic drawing of the working parts and the method of supplying it with water. This ram is shown by Fig. 3.

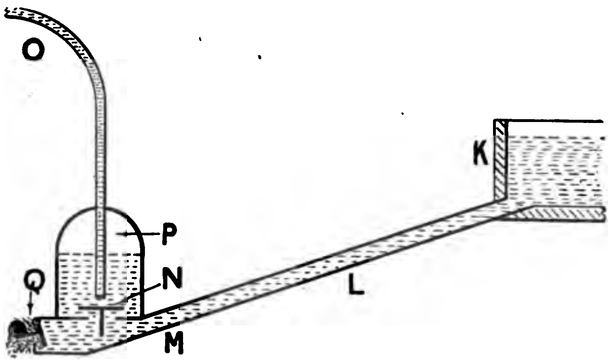

FIG. 3.

In the drawing, K is the drive-water tank; L is the drive-pipe which conveys the water to the ram; M is the body-pipe of the ram; N is the

delivery-valve which opens upwards into the air-vessel; O is the delivery-pipe; P is the air-vessel; and Q the dash or working valve. The dash-valve is hinged on the top edge, and has a counter-

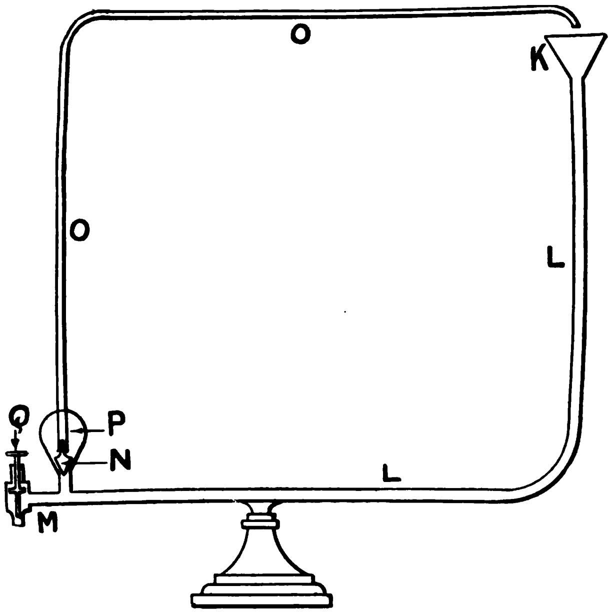

FIG. 4.

balance to assist the reflux action of the water in the drive-pipe after the force of the forward flow has been exhausted.

Fig. 4 is a glass working model of a similar ram, which can be purchased for four shillings and is useful for demonstrating to students in a class-

room. The various parts are lettered to correspond with those in Fig. 3. The only difference is that the dash-valve works up and down in the glass model, instead of to and fro as shown in the diagrammatic sketch, Fig. 3.

Being made of transparent glass, the working of the valves in Fig. 4 can be clearly seen.

ACTION OF HYDRAULIC RAM

The action is as follows :—When the ram is first started to work, the valve Q is open, and the water flowing down the pipe L escapes through the valve. The velocity of the flow increases until it attains sufficient speed to dash the valve Q on to its seating. The flow is thus suddenly arrested, and the shock of the water would break the body-pipe unless it was made very strong. If a hole was made through any side of the body-pipe the shock, caused as stated above, would eject a stream of water through such hole with great violence.

In Figs. 3 and 4 the hole is shown on the upper side of the body-pipe M, and is covered by the valve N. This valve is for the purpose of preventing any water that has been forced into the air-vessel P returning into the body-pipe. In addition to the weight of the valve N, there is considerable pressure exerted by the water above it. Hence, the force with which the water is injected into the air-chamber must be sufficient to lift the valve and the water immediately above it, and also to further compress the air in the air-chamber, which is already reduced in volume by the pressure exerted by the water in the delivery-pipe.

As soon as the downward flow of the water in L has been arrested, a reflux action takes place. That is, the whole of the water from end to end of the drive-pipe, and also that in the tank near the inlet end of the pipe, flows backwards and upwards. This reflux action is finally overcome by the downward pressure of the water from the tank K. There is then a pause for a fraction of a second, during which the valve N closes and that at Q re-opens. The downward flow of water in the drive-pipe again commences, the valve Q is again dashed on to its seating, more water is forced through the valve N, and the whole of the proceedings are repeated. The action is continuous for an indefinite length of time. A stoppage takes place only when the supply which works the ram fails, or when the working parts break or otherwise become out of order or adjustment.

CHAPTER IV

WATER SUPPLY FOR HYDRAULIC RAMS

WHEREVER there is an open running stream of water, and that stream has a fairly good fall, the water can be dammed back so as to obtain a 'head' to work a hydraulic ram.

Fig. 5 is a diagrammatic plan of such a case. In the drawing R is the dam or weir; S a grated inlet to the drive-tank, T; and U the drive-pipe. If circumstances permit, the latter should be 2 ft. or 3 ft. below the ground, so as to be beyond the influence of frost. The ram is fixed in an underground pit or a house above ground, at V. The tail water returns into the stream at W.

Where the ram is to raise water to only a moderate height—say 30 ft. or 40 ft.—a difference of only 2 ft. or 3 ft. between the levels of the stream water at S and W will give satisfactory results, provided the quantity of water is sufficient and the drive-pipe is of a suitable length. Where, however, it is possible to have a greater head—say 6 ft. or 8 ft.—better results will be obtained.

Many rams are fixed by the sides of small rivers or canals; suitable places being near the locks. The necessary head is given by the water above the upper or higher gates of the locks. The surplus water from the ram returns into the stream

below the bottom gates, the arrangement being similar to that shown by Fig. 5, in which the dam, R, may be taken as the higher gates of the lock.

In all cases the inlet to the drive-tank should be submerged in the stream water. If the end of the pipe is too near the surface of the water, floating matters are carried into the drive-tank. For similar reasons it is advantageous to fix a strainer on the inlet end of the pipe. A brick chamber with a grated inlet is shown at S, Fig. 5. This

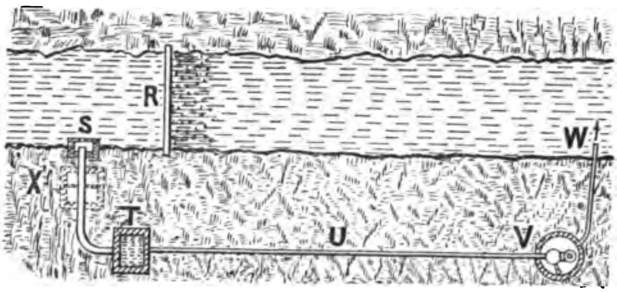

FIG. 5.

strainer will not only keep out reeds and floating tree leaves, but will also prevent rats entering or fish being sucked into the pipe. The ice that forms during cold weather rarely exceeds 3 in. or 4 in. in thickness, and if the inlet end of the pipe is submerged a little more than that depth, the working of the ram will continue during frosty weather.

Where the stream water is not very clear it should be passed through a filter-bed constructed in the position shown by the dotted lines at X, Fig. 5. The filtering material should have all fine

sand washed out of it before placing it in the tank, otherwise the grit will wash into the ram and injure the valves.

A filter is often necessary for reasons beyond those already given. At a mansion in Somersetshire a hydraulic ram is driven by means of water from a small lake, which is stocked with geese and ducks. The scum caused by these birds is drawn into the drive-pipe of the ram and forms a slimy coating inside. When this coating has accumulated to such an extent as to interfere with the working of the ram, a long length of galvanised iron wire cable, on the end of which a bunch of iron wire netting is fastened, and which is kept in readiness for the purpose, is passed through the pipe to clear away the obstruction.

In Warwickshire a ram was fitted up and supplied with water from a lake of considerable extent. The lake is supplied mainly from springs and the water is fairly good. Because, however, of the reeds and rushes that are growing in it at certain seasons of the year, the water has a peculiar odour and taste imparted to it. The odour is more particularly noticeable when hot water is being drawn from the taps in the mansion. The working of the ram was affected by the rushes, which broke away from their roots and, drifting towards the ram inlet, were sucked into the drive-pipe.

Fig. 6 is an illustration of the end of the drive-pipe immersed in the lake water. For keeping out the rushes, a tinned copper wire balloon-shaped grating was attached to the end of the pipe, and a large size, rectangular, galvanised iron wire grating fixed as shown in the drawing. The gratings intercepted any rushes which came broadside on,

but those which floated endwise towards the grating passed through with the water to the ram. For these and other reasons the use of such gratings is not advisable.

When such gratings are fixed it is not possible to attach a valve to the inlet end of the pipe; or, if convenient to fix a valve, owing to its position

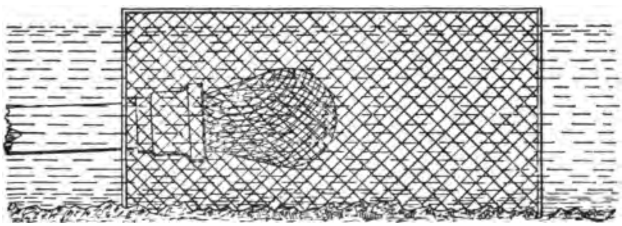

FIG. 6.

it is difficult of access for opening and closing when necessary to do so. The item of frost in the winter time, too, cannot be ignored.

Where rams are supplied as above described, it is far better to pass the water through a filter tank. In the Warwickshire case a filter was specified, but omitted because of the cost. Fig. 7 is a section of a suitable filter tank which can be constructed without in any way altering the levels of the water, whether it be drawn from a lake, a pond, or a running stream.

To construct the tank, first make the necessary excavations in the side, or any other suitable position, of the bank of the stream or lake. Then lay a bed of concrete so as to extend about 9 in. beyond the outsides of the walls of the tank. The walls can be built of brickwork or concrete.

On the water side of the tank the bottom of the wall should be built in cement to a height of 6 in. or 9 in. above the level of any mud in the bed of the lake or stream. Above this level the wall should be perforated if made of concrete, or have several open joints if made of brickwork, for

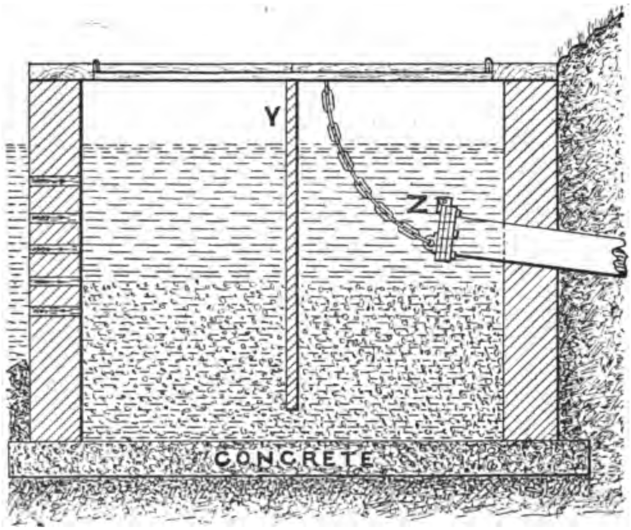

FIG. 7.

the water to pass through into the filter. A division made of slate, or any other stone, should be fixed as shown at Y, and the tank should be filled on both sides of this division, and up to about 4 in. or 6 in. below the end of the drive-pipe, with clean, sharp gravel, from which all fine sand has been sifted.

The wall next the bank, or on any side against which earth is resting, should be strongly built and made watertight—the latter for two reasons: firstly, so that water shall not trickle through the wall and wash away the backing of earth; and, secondly, to prevent ground water flowing into and mixing with the water in the tank.

When the surroundings are suitable, the tank can be left open; but if cattle are in the neighbourhood and likely to walk or tumble into the tank, or dead leaves from trees to drift into it, an oak covering with hinged doors or flaps should be provided. Where a valve is fixed on the end of the drive-pipe, it is sometimes advisable to have a lock fixed on the flap or door. The lock is to prevent interfering visitors tampering with the valve or surreptitiously stopping the supply to the ram. Wandering tramps and mischievous boys should be guarded against.

CHAPTER V

COLLECTING WATER TO SUPPLY A RAM

WHERE there is no running stream or lake available for working a ram, or where such water is available but is not suitable for use, a supply can sometimes be obtained out of ground which is satisfactorily situated. In a part of South Wales, trial holes were made in a large field which had a slope towards one side. Clay was found under a superlayer of gravel and earth, and a few trickling streams of water were discernible. A trench was dug across the lower side of the field and down to the clay. The trench was filled with well-puddled clay, which held up the water that was trickling through the gravel over the clay stratum. The collected water was directed into a sump, or small underground reservoir, constructed to receive it. The results were satisfactory, sufficient water being obtained to work a ram and supply a mansion about two miles distant.

In another case, in Sussex, a very large area of park land was drained with agricultural pipes, and the water collected, as shown in the accompanying sketch plan, Fig. 8.

The dotted lines represent open-jointed collecting pipes, which converge into the tank, A. This tank was of a large size, and had a filter-tank

constructed for intercepting any sand that was brought in with the water.

Because of the slope and position of the collecting ground, the drive-tank, B, had, of necessity, to be about a quarter of a mile distant from A. The connection between the tanks was made with

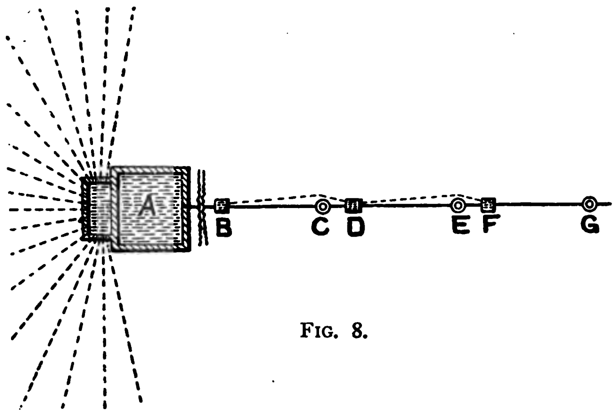

FIG. 8.

4-in. vitrified stoneware pipes, jointed together with Portland cement.

We may leave our subject for a brief period to mention that a most curious experience was gained after the above 4-in. pipes had been laid for about two or three days. One long, straight length of the piping was found to be raised in the form of an arch above the bottom of the trench in which it was situated. The crown or highest part of the arch was between 3 in. and 4 in. above the bed of the trench. Several of the pipe sockets were also split and broken, and a considerable length of the piping

had to be relaid. There is no room for doubting that it was the swelling of the Portland cement on setting that was the cause of the trouble described. Hence the advisability of exercising care when selecting the cement to use for jointing stoneware pipes for conveying water.

Again referring to Fig. 8, at C a medium size ram was fixed. The tail-water from this ram flowed into another tank at D, to supply another ram fixed at E. The waste-water from the latter ran into a third tank at F, and worked a small size ram at G.

The available water supply was very limited, and not sufficient to drive a ram large enough to meet the requirements of the mansion. Therefore two medium and one small size rams were used as described. The three rams all forced water into the same delivery-pipe, and supplied an underground reservoir on an eminence about half a mile distant.

In each tank a hinged flap-valve was fixed, similar to that shown at Z, Fig. 7. The dotted lines between tanks B and D, and D and F, respectively represent pipes laid to convey any overflow water to the tank immediately below. By this arrangement of flap-valve and overflow, if either of the upper rams ceased to act, or had to be thrown out of use for the purpose of making repairs, the others could still be kept at work.

It frequently occurs that water springs are situated in woods or clumps of trees. The ground on which the trees are growing is often very irregular, and little brooklets are found to be trickling through channels scoured on the surface of the earth between the trees. In many cases it is

necessary to use this water for domestic purposes in country mansions.

Where the levels of the ground are favourable, the water from these small streams can be collected into a tank and used for driving hydraulic rams; but where the ground is very irregular, and it is difficult to make use of natural channels, it then becomes necessary to construct small aqueducts (which may be of brickwork or of concrete) to convey the water to the ram drive-tank. Where cost is a bar to the construction of proper aqueducts, with arches to span hollow or sunken places, open wooden troughs, having the ends jointed together with puddled clay, are often used. For crossing low levels the troughs are supported on rustic wooden trestles, usually made of rough timbers obtained on the spot.

FUTILITY OF RAISING WATER TO WORK HYDRAULIC RAMS

For water to be useful as a motive power it must be situated in a position higher than the appliance it is to actuate. To get the water into an elevated position a certain amount of energy has to be exerted. This energy may be derived from man, animal, or power driven machinery, or from the natural action of the sun and wind.

If 100 gallons of water weighing 1,000 lb. has to be raised to a height of 100 feet, then 1,000 lb. $\times$ 100 feet = 100,000 foot-pounds of energy is necessary to be exerted to raise the water.

This is the net energy necessary for raising the water. Further energy is required to overcome the friction of the moving parts of the appliances used

and the friction of the flow of water inside the channel through which it is conveyed to its destination. A further allowance must also be made for the power to exceed the resistance to be overcome, otherwise power and resistance would be in a state of equilibrium, and effective work would not be accomplished.

If the values of these factors are added together and their total equals, say, one-third of the power necessary for the actual raising of the water, then $\left(\frac{100{,}000 \times 4}{3} =\right)$ 133,333 foot-pounds must be the gross or total power exerted on the appliances used for raising the 100 gallons to the height of 100 feet.

Although this power is necessary to raise the water, only 100,000 foot-pounds of energy is stored in the elevated water, and a greater amount cannot be given off by it. In its application to doing work, probably one-third of the stored energy would be absorbed by friction of the appliances used and other details, as previously dealt with. Consequently the elevated water would be capable of doing only $\left(\frac{100{,}000 \times 2}{3} =\right)$ 66,666 foot-pounds of effective work; and this is so whether the water comes down in a volume or is allowed to fall drip by drip into the appliance it has to work.

Hence, if the water to work a hydraulic ram had to be raised to a height (say, pumped from a well) by mechanical means, there would be a great waste of power, because the appliances used for raising the water would be capable of doing what was required without the use of a hydraulic ram.

With a natural supply of water situated in an elevated position, the energy which raised the

water was derived from the sun and other of Nature's forces.

Water raised by natural forces contains the same amount of energy as the water which is raised by machinery made by human hands. This applies to large or small quantities of water, which is stored at elevations of many feet or yards, or only a few inches.

For the foregoing reasons a hydraulic ram cannot be economically worked unless a sufficient volume of water, raised by Nature's forces to a suitable height, is available.

There are, however, other hydraulic appliances —such as hoists, presses, lifts, capstans, &c.— which are advantageously worked by water, raised by either natural or mechanical means, or forced under pressure into main pipes by power-driven machinery. In the latter cases the economy is derived by having the whole of the energy developed in one place, and then transmitted and distributed to other places situated at a distance. This branch of hydraulics is, however, beyond the scope of this book on Hydraulic Rams.

CHAPTER VI

Sluice-valves on Drive-pipes to Rams

A flap-valve should always be fixed on the inlet end of a ram drive-pipe. A sluice-valve should also be fixed on the inlet end of the ram itself. This valve saves a great deal of time when making repairs or adjustments to the ram, and obviates the trouble of going to the drive-tank to open or close the flap-valve.

The sluice-valve should have a clear straightway through it, so that the line of flow of the current is not broken by changing its direction two or three times, as is the case when ordinary valves are used. Neither should there be any parts inside the valve where air can accumulate or be pent up. Such confined air would act as a spring buffer and rob the 'shock' of the water of some of its force. For this reason the valve should be fixed sideways—that is, with the spindle in a horizontal instead of in a vertical position.

Figs. 9 and 10 show two such valves. Fig. 9 is screwed for iron at one end and has a union on the other end for soldering to a lead drive-pipe. Fig. 10 has flanges on the ends for connecting to cast-iron pipes. Either of the valves would probably require to be repaired or renewed at times; hence the necessity of being able to take it out

without running the risk of breaking any part of the ram or the drive-pipe. For connecting to a lead pipe the valve should have a ground-in union and thus avoid having to use any washers, which are always liable to 'spring' at each shock of the dash-valve.

The flanges on the other valve could have 'trued' or turned faces so that no packing would

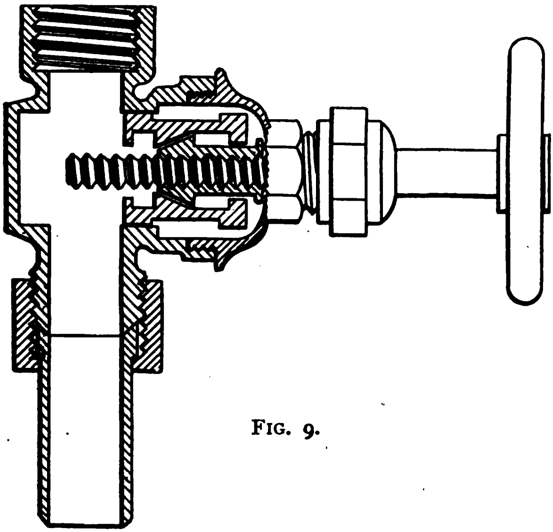

FIG. 9.

be necessary. But because such trued faces would rust and 'grow' together, a millboard packing should be used, thus enabling the flanges to be separated without much trouble. Indiarubber rings are sometimes used, but are not so good as the millboard because of their flexibility and

likelihood of 'giving' at each shock caused by the closing of the dash-valve.

Fig. 9 shows the valve open and a clear straight-way through the body. Fig. 10 shows the valve closed. When the wheel head is turned round,

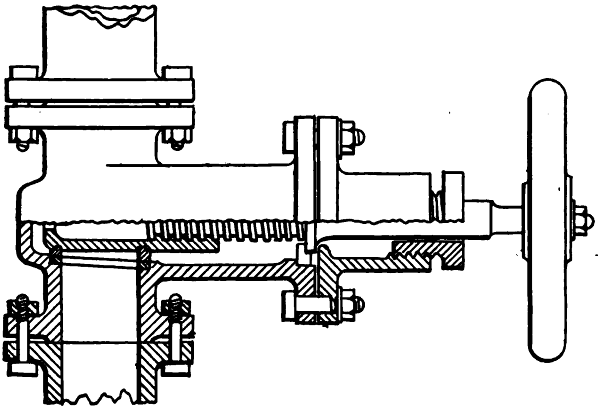

FIG. 10.

the valve is drawn aside by the screwed spindle, thus leaving a straight-way through the body for the water to flow through.

The chambers into which the valves are drawn are those referred to in a previous paragraph as being liable to contain pent-up air.

CHAPTER VII

MATERIALS FOR DRIVE-PIPES

FOR small-size rams the drive-pipes are made of lead or wrought-iron, the latter either plain or galvanised. For large-size rams cast-iron is used.

When the drive-pipes are made of lead they should be very strong and not less than the following weights :—

¾ in.,	9 lb.	per yard
1 in.,	12 lb.	„
1¼ in.,	16 lb.	„
1½ in.,	21 lb.	„
2 in.,	28 lb.	„

and the joints should be 'wiped' and not copper-bitted.

If made of plain wrought-iron the pipes should be 'steam' strength, and of a larger size than when lead is used. The larger size is to allow for corrosion by rusting, which reduces the waterway and interferes with the motion of the water. It is better, too, when such pipes are galvanised to have them a little larger than when made of lead, owing to their being rough inside.

When necessary to have them 2 in., and larger, it is usual to fix cast-iron drive-pipes, not only as an economy, but because iron is less liable than

lead to sag in soft or boggy earth, or be lifted by roots when laid in ground situated near trees. It is also important that such pipes should be so laid that no air can accumulate in them, as would be the case if any parts were either raised or lowered, thus forming bags or traps.

Cast-iron pipes should be protected as much as possible from rusting, for reasons already given, and also because of pieces of rust passing into the ram and interfering with the seating of the delivery-valve in the air-chamber. This rusting takes place more especially after the ram has been left unused for a time. Even when, owing to some disarrangement, it has stopped for a day or two only, a quantity of rust has given trouble on restarting the ram.

Cast-iron pipes coated inside with a wash made of freshly slaked lime have sometimes answered very well. When done in a proper manner with the solution suggested by Dr. Angus Smith they are very good, but a great deal depends upon the method of coating. This should be done in the foundry, where the pipes are cast, and when they are hot from the moulds. When done afterwards, or painted by hand, the pipes frequently rust, and complaints have been made of a flavour of the coating material being imparted to the water.

Cast-iron pipes with flanged ends are sometimes used as drive-pipes, the flanges being bolted together with a packing between. The proper way for making such joints was described when writing on sluice-valves.

Socketed cast-iron pipes are those mostly used, and they should be very strong or they will break under the water shocks inside.

The dimensions and weights should not be less than as follows :—

Inside diameter in inches.	Length exclusive of socket.	Thickness in decimals of an inch.	Weight per length.		
	Feet.		Cwt.	qr.	lb.
2	6	·31	0	1	20
2½	6	·33	0	2	7
3	9	·35	1	0	14
4	9	·39	1	2	20
5	9	·42	2	1	5
6	9	·45	2	2	0

The joints on cast-iron socket pipes, when not coated with Smith's solution, are sometimes made with rust cement. When the pipes are coated the cement does not 'rust' properly, and the joints are not at all good under those circumstances.

The constituents of rust cement are sal-ammoniac, flour of sulphur, and iron borings from an engineer's shop. When the latter are 'oily' they should be made red hot to burn off the oil. The proportions should be carefully attended to, because if the cement is made too strong it will rust with such violence as to burst the pipe sockets.

The proportions for medium-setting cement are by weight as follows :—

1 powdered sal-ammoniac.
2 flour of sulphur.
100 iron borings.

And for slow-setting :—

2 powdered sal-ammoniac.
1 flour of sulphur.
200 iron borings.

Sometimes urine is used instead of sal-ammoniac.

When coated pipes are used, caulked lead joints are the best. The sockets should have grooves inside, as shown at H, and the spigots have beads on the ends, as at I, Fig. 11. When making such joints care should be taken to have the bore of the pipe properly aligned, to avoid having sharp edges inside for the water to impinge against and cause eddies.

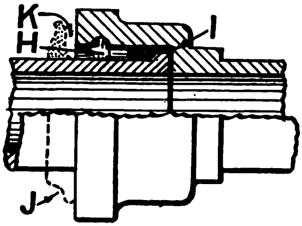

FIG. 11.

When making caulked joints it is usual to first 'yarn' them; that is, to drive or caulk into the annular space between the pipe end and the socket a few strands of yarn or loosely twisted soft rope. The yarn is for the purpose of preventing the molten lead running into the pipe. Too much yarn should not be used, or the joint will be weak, and the lead driven out by the shock of the water inside when the dash-valve closes.

After yarning the joint a clay band is usually placed outside, as shown by dotted lines at J, and molten lead poured into the opening left in the top at K. The lead shrinks as it cools, and to make it fit tight in the socket it is 'staved' on the exposed surface to make it expand, and thus fill up the void left after the shrinkage has taken place.

Because yarn will rot away in time, and when tarred imparts a flavour to the water, a better joint is made by caulking the bottom of the socket with pieces of rod lead, or with thick sheet lead cut into strips about half an inch wide. About three strips are used, each one being well caulked before placing in the next one. The remainder of the space is filled with molten lead and staved as before described.

Another material recently introduced is 'lead-wool,' which consists of finely divided strips of lead twisted into a rope. Lead-wool does not rot away in the same manner as yarn.

A turned and bored joint is shown by Fig. 12. The beaded end at L is turned true to fit the bottom of the socket. This joint has the advantage of ensuring a true bore in the pipe, and does away with the necessity of using yarn.

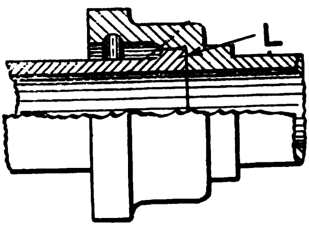

FIG. 12.

All pipes in connection with rams should be laid not less than 2 ft. below the ground surface, so as to be beyond the reach of frost. Running water does not freeze to the same extent as that which is still. But because rams sometimes stop for the want of attention, the water in the pipes will then freeze during cold weather. This causes some trouble, especially when a mansion or other premises depends upon the water supplied by the rams.

CHAPTER VIII

Sizes of Drive-pipes to Rams

The flow of water through a drive-pipe to a hydraulic ram is not continuous, and can be best described as 'stop and start.' This causes the speed of flow to vary very much. The speed is also governed to a great extent by the length of the pipe and the height to which the water is being raised when the ram is working.

The author has carried out a large number of experiments with the view to formulating rules for calculating the necessary sizes for drive-pipes. To enumerate all the experiments, and the conclusions arrived at, would be tedious, and would not serve any really good purpose. It would also have a tendency to cloud what should be clear and easily understandable by ordinary men who have to deal with rams. With this principle in view only a few results will be here dealt with.

With a 1″ drive-pipe, 60′ 4″ long, it took 4 minutes 10 seconds to run a measured quantity of 28 gals. of water through the ram when the dash-valve was held down. With the same quantity of water, and the ram pumping to a height of 64 ft., the time occupied was 9 minutes 10 seconds, or $9' \ 10'' \div 4' \ 10'' = 2{\cdot}2$, or a little more than twice

as long as when the flow of water through the drive-pipe was continuous.

Under exactly similar conditions, but with the drive-pipe 15 ft. long, the times were 3 minutes 30 seconds and 8 minutes 45 seconds respectively. This gives $8' 45'' \div 3' 30'' = 2{\cdot}5$.

With the drive-pipe equal in length to the vertical distance between the dash-valve and the surface of the water in the drive-tank, which was $7' 4''$, the respective times occupied in discharging the same measured quantity of water, as in the other experiments, were $2' 20''$ and $8' 30''$, and $8' 30'' \div 2' 20'' = 3{\cdot}64$.

A mean of the three foregoing results $= 2{\cdot}78$, or, say, 3. That is, the drive-pipe to the ram should be of a size capable of discharging about three times the quantity that would pass through if the dash-valve was held down, so that the flow was continuous.

Put in another way :—The average speed of the forward flow of water is only about one-third of that of a continuous flow. Although the variations in different makers' rams and the conditions under which they are fixed are considerable, it may be taken as a fair average that the drive-pipe to a ram should be of a size capable of discharging three times the quantity of an ordinary service-pipe fixed under similar conditions with regard to the head of the water on the pipe.

To work an example :—Assume that to raise a certain quantity of water to a given height it will be necessary to supply the ram with 30 gals. per minute ; the height of the feed water being 8 ft. above the ram, and the length of the drive-pipe 90 ft.

The calculation should be based on the assumption that ($30 \times 3 =$) 90 gallons would be required, although only 30 gals. are actually used.

The size of pipe to deliver this quantity can be found by Box's rule, which is: $d = \left(\frac{G^2 \times L}{H}\right)^{\frac{1}{5}} \div 3$; in which d=diameter of pipe in inches, G=gallons per minute, L=length of pipe in yards, and H= head of water in feet.

For the solution of the problem:—

$$d = \left(\frac{90^2 \times (90 \div 3)}{8}\right)^{\frac{1}{5}} \div 3 = 2{\cdot}6256 \text{ in.}$$

The nearest stock size of pipe is 3 in. In the above case the 3″ pipe should be used, because there is slight retardation of flow caused by the friction of the water on the edge of the inlet end of the drive-pipe, which friction was not taken into consideration in the data on which the problem was worked.

In all cases the diameter of the body-pipe of the ram should be the same as that of the drive-pipe—that is, it should neither be smaller nor larger.

Increasing the size or diameter of the drive-pipe does not increase the working capacity of the ram, because the latter, including the dash-valve, has to be enlarged in proportion. Otherwise the force of the shock will be reduced by being spread over a larger area of surface, both on the valve and on the inside of the body-pipes.

With a small-size drive-pipe of a good length, and a dash-valve of proportionate size, the same parallel column of water moving in a body would strike on a smaller surface with much greater

results than would be the case if the surface of impact was larger.

There are several rules given in engineers' books for the proper sizes of drive-pipes; but, on scrutiny, they are not found to be reliable for rams of modern construction. The efficiency of the earlier makes of rams was far below that of present-day appliances; therefore the proper sizes of such pipes can best be found on the lines laid down in this Chapter.

SIZES OF DELIVERY-PIPES

With regard to the proper sizes for the delivery-pipes of rams it would be a difficult matter to lay down a hard and fast rule, and we cannot do better than use that for the delivery-pipes of lift-pumps, which is, that they should not be less than half the diameter of the barrel or, in the case of rams, of the drive-pipe.

The following table about agrees with this, and also some ram-makers' advice on the subject:—

Drive pipe.	Delivery-pipe for short distances.	Delivery-pipe for long distances.
1 inch.	⅝ inch.	½ inch.
1½ "	½ "	¾ "
2 "	¾ "	1 "
3 "	1¼ "	1½ "
4 "	1½ "	2 "
6 "	2½ "	3 "

For long distances, of ¼ mile and upwards, the third column should be used; also in places where proper attention is not paid to the rams, and their air-vessels properly re-charged when necessary.

CHAPTER IX

LENGTHS FOR THE DRIVE-PIPES TO HYDRAULIC RAMS

SUCCESS or failure in the working of a hydraulic ram depends almost entirely on the size and length of the drive-pipe. Although here dealt with separately, in practice size and length respectively must be taken conjointly; the former for supplying the necessary volume of water, and the latter for giving force to the water thus supplied.

Assume that 10 gals. of water are passing into a ram in one minute. If this water flows from a height of 10 ft., then, nominally (10 gals. × 10 ft. =) 100 foot-gallons of flow-energy is exerted.

But if the water flows through a drive-pipe which is 50 ft. long, it does not exert the same force in the ram as it would through a similar pipe 100 ft. long.

Assume a pipe 2″ in diameter, and further assume that a cubic foot of water weighs 62·5 lb. The weight of water contained in 1 ft. of 1 in. pipe $= \left(\frac{62{\cdot}5 \text{ lb.} \times {\cdot}7854}{12'' \times 12''} = \right) {\cdot}34$ lb.

The water contained in 50 ft. of 2″ pipe weighs ($50 \times 2^2 \times {\cdot}34 =$) 68 lb. The 100 ft. of 2″ pipe would hold double that quantity, or 136 lb. It is obvious that an iron rod which was 2″ in diameter

and weighed 68 lb. would not strike an end blow with such force as a similar rod of the same diameter and weighing 136 lb. Each rod falling endways from the same height would travel approximately at the same speed.

Water, however, would not travel at the same speed in the two pipes because of the extra friction in the longer pipe, as the following calculations show.

Eytelwein's formula for finding the velocity of flow in water-pipes is $V = \cdot 9\sqrt{2fh}$, in which $V =$ velocity of flow in feet per second; $f =$ fall in feet per mile; and $h =$ hydraulic radius, or diameter of pipe in feet $\div 4$.

For the pipe 50 ft. long, and a head of 10 ft., the fall in feet in two miles =

$$\left(\frac{1760 \text{ yds.} \times 3 \text{ ft.} \times 10 \text{ ft.}}{50 \text{ ft.}} \times 2 =\right) 2112.$$

For a 2″ pipe, $h = \left(2'' = \dfrac{2''}{12} =\right) 0{\cdot}166$ ft. and $\dfrac{0{\cdot}166}{4} = \cdot 0415$.

And $V = \cdot 9\sqrt{2112 \times \cdot 0415} = 8{\cdot}424$ ft. per second.

For the 2″ pipe which is 100 ft. long, $2f = [(1760 \times 3 \times 10) \div 100] \times 2 = 1056$.

And $V = \cdot 9\sqrt{1056 \times \cdot 0415} = 5{\cdot}958$.

It has already been shown that the mean velocity of flow in a drive-pipe to a ram is only one-third the velocity in an ordinary water-main. At the moment of impact with the dash-valve of a ram, however, the velocity of flow may be taken as being two-thirds the theoretical velocity.

On this supposition, and also that the beats of

the valve are once per second, with the 50 ft. long drive-pipe the dash-valve will strike against its seating with a force of

$\left(68 \text{ lb.} \times \frac{8{\cdot}424 \times 2}{3} = \right) 382$ velocity-pounds.

For the pipe which is 100 ft. long, the force exerted will be $\left(136 \text{ lbs.} \times \frac{5{\cdot}958 \times 2}{3} = \right) 540$ velocity-pounds.

The calculations show that the water in the 100 ft. of pipe develops an energy of

$\left(\frac{100 \times 540}{382} = \right) 141$, as compared with 100 for the pipe which is 50 ft. long.

In a future Chapter will be given the result obtained under varying conditions of experiments with an actual ram.[1] During these experiments the movement of the water inside the air-vessel (as seen in the glass gauge fitted at the side for this and other purposes) was found to differ very much when the actions caused by long and short drive-pipes were compared.

With the short drive-pipe the water appeared to be 'jerked' into the air-vessel; but with the long drive-pipe the water appeared to be 'pushed' into the air-vessel, if a difference in the two forms of expression can be understood as applying to the actions. In other words, with the short drive-pipe, at the same instant that the dash-valve closed water was quickly forced into the vessel; but with the long drive-pipe the water continued to rise for a short time afterwards, thus showing that the motive force was sustained for a longer time.

[1] See p. 58.

This difference of action between the use of the two pipes was further illustrated when stopping the working of the ram by holding the spindle of the dash-valve between the fingers. When the short drive-pipe was in use very little effort was required to hold the valve tight up to its seating; but when the long drive-pipe was used a very strong pulling power was found to follow each stroke of the dash-valve. The pull was repeated two and three times at intervals of about a second or a little more. In the first case the action of the ram could be immediately stopped, and in the second case the valve had to be held firmly for a few seconds, otherwise the ram would again start into action. The conclusions to be drawn from the foregoing observations are: that the oscillation of the water in the drive-pipe to a hydraulic ram is the same as the oscillation of the water in a water service-pipe. When a draw-off tap attached to a short length of service-pipe is quickly closed, only a single 'thud'. is heard; but when a tap on a long length of service-pipe is quickly closed a series of 'thuds' follow each other, and decrease in intensity until the water becomes motionless, when all sound ceases.

Although the force of the moving water is greater with the longer pipe, and a larger quantity is forced through the delivery-valve at each stroke of the dash-valve, it will be shown in the Tables of Experiments (see pp. 58 to 61) that the beats of the valve are slower with the longer pipe, and also that a longer time is necessary for a measured quantity of water to pass through the ram. This matter, however, will be further dealt with when

the results are given of a few selected experiments out of several hundreds that have been made.

An ordinary ram-maker's rule is :—

Length of drive-pipe = vertical height the water is to be raised.

This rule, however, cannot be accepted as being suitable for all conditions, because in one case the length of the delivery-pipe may be only 100 yards; and in another case the pipe may be a mile or two long.

Mr. James Keith, a well-known maker of rams, in a table supplied by him to the author of Clarke's 'Tables,' gives the lengths of drive-pipes as being from 40 yards for a small-size ram to 160 yards for one of a large size, the head of drive-water above the ram being 10 to 20 ft., and the height to which the water is raised 100 ft.

The following Table is an average working rule for finding the proper lengths of drive-pipes, when h does not exceed 100 ft. and the distance of the reservoir does not exceed half a mile. H denotes the height in feet of the drive-water above the ram, and h the height in feet to which the water is raised :—

H = . . .	2	3	4	5	6	7	8	9	10
h × . . .	3·0	2·8	2·65	2·45	2·25	2·0	1·85	1·65	1·5
Where the height exceeds 100 ft. h × . .	3·5	3·25	3·0	2·8	2·6	2·5	2·25	2·1	2·0

Large numbers of rams are fitted up with drive-pipes much shorter than those given above. Such appliances, however, are always very troublesome to adjust. The author's experience is that with

a short drive-pipe the dash-valve is apt to chatter and then hang up. This hanging up is due to the water not reflowing in the drive-pipe sufficiently far to form a vacuum beneath the valve. If the valve only partially opens it chatters, and then remains closed.

It should, however, be remembered that if the drive-pipe is too long the shock of the drive-water, even when working under a low head, is sometimes so great as to smash or otherwise injure either the delivery or the dash valve. Unnecessary strain is also brought to bear on the body-pipe of the ram and on the joints of the drive-pipe.

HEIGHT OF DRIVE-WATER TANK ABOVE RAM

Head or height of the drive-water tank above a ram has to be considered, because active force is not imparted to the water unless it flows or falls from a height.

The higher the head of the drive-water, the higher the velocity of flow through the drive-pipe; and the greater the subsequent shock of the dash-valve, the larger the quantity of water forced through the delivery-valve at each such shock.

Too great a head, however, is not advisable, because of the injury done to the ram or the working valves, or to the drive-pipe and the joints in it.

When dealing with the head of water to work a ram, the length of drive-pipe has to be taken in the same connection. It has been before shown that retardation of flow by friction is increased in proportion to the length of the pipe.

Box's rule for finding the head to discharge a

given number of gallons per minute through a pipe of a stated length and diameter is as follows :—

$H = \frac{G^2 \times L}{(3d)^5}$, in which H = head of water in feet; G = gallons discharged per minute; L = length of pipe in yards; and d = diameter of pipe in inches.

To work an example: Assume the drive-pipe to a ram is 2 in. in diameter and 100 ft. long, and that 20 gals. per minute must pass through the ram to raise the desired quantity to the storage tank or reservoir.

It has already been shown that the pipe must be capable of discharging three times the actual quantity that passes through the ram; but in the assumed problem the size of the pipe is given as being 2 in. Hence, the drive-tank must be at a height that will give a velocity of discharge equal to (20 × 3 =) 60 gals. per minute.

On this basis $H = \left(\frac{60^2 \times (100 \div 3)}{(3 \times 2)^5} = \right)$ 15·416, or, say, 16 ft. as an allowance for loss of head by friction of entry into the inlet end of the drive-pipe.

In all cases H, or head of water, is measured from the surface of the water, and not from the bottom or any intermediary depth of the tank.

By the above rule any variations of the assumed problem can be readily found.

In many cases the level of the water in the drive-tank varies considerably. This, however, will be dealt with in the Chapter on automatic-acting gear for stopping the ram when the supply is so reduced as not to be sufficient to work it.

CHAPTER X

EXPERIMENTAL RAMS

FIG. 13 is a drawing of a hydraulic ram made by the plumbing students for an Industrial Exhibition at the Polytechnic, Regent Street, London. The whole is made of lead, excepting the delivery-valve inside the air-vessel at L, and the dash or working valve at M. The ram was worked from a cistern (N) made out of 6 lb. sheet lead, with a wiped soldered seam on the side and a wiped flanged seam round the bottom. This crudely-made ram, with a working-head of 5 ft., raised water to a height of 50 ft.

The drive-tank, N, was kept filled with water from a main, a ball-valve being fixed for automatically stopping the supply when the ram was not working. The dash and delivery valves were built up out of odd pieces of iron and brass which happened to be at hand. The screws only were purchased. The stop-cock, O, had a full or clear waterway, and was an old one discovered lying about in the workshop.

The drawing is made to scale, the author having been applied to several times for particulars for making such a ram. If any reader feels disposed to make one, he should use a 1-in. drive-pipe and a ½-in. delivery-pipe. He can also use a 1½-in.

ordinary plumbers' spindle-valve, fixed so as to open downwards, for the dash-valve, and a ½-in. spindle-valve for the delivery. The stop-cock, O, s not actually necessary, but it is more convenient

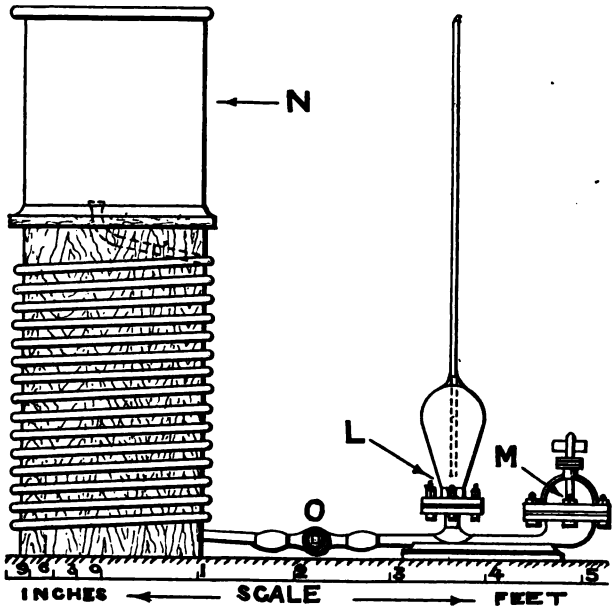

FIG. 13.

than a plug in the inlet end of the drive-pipe for stopping the supply to the ram.

Fig. 14 is a drawing of a small (or A size) ram supplied to order by Mr. James Keith, and fitted up, as shown, for experimental purposes, and for demonstrating to the students attending the plumbing classes at the Polytechnic, Regent Street.

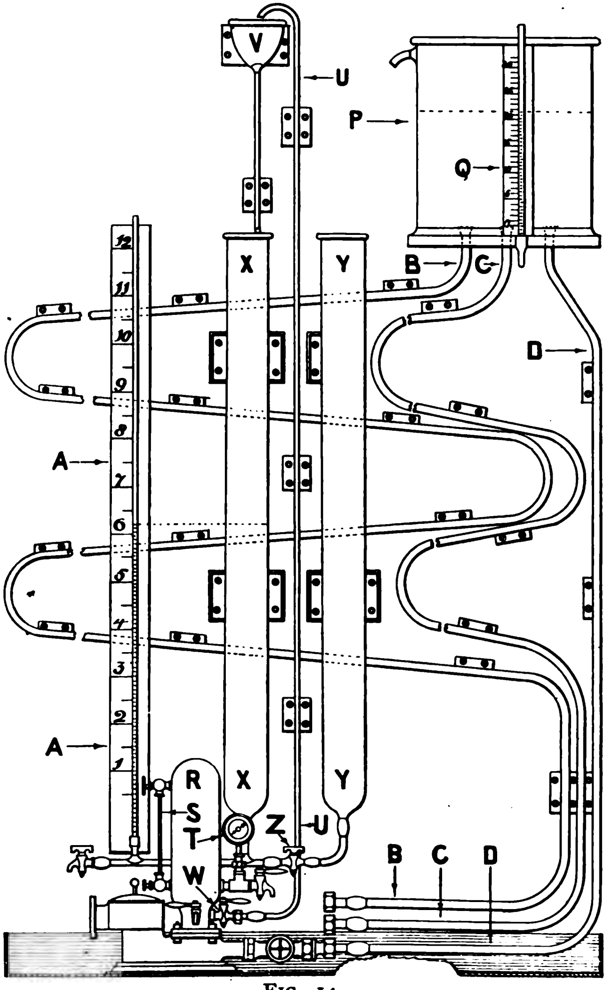

FIG. 14.

In the drawing the drive-tank, P, is the old one that was described in connection with the ram shown in Fig. 13. The glass gauge at Q is for showing the quantity of water, in gallons, in the tank. For the sake of being exact, the gauge was marked from the water which was actually measured into the tank.

The ram R, Fig. 14, stands in a large zinc-lined wooden sink, from which a pipe is fixed for conveying the waste water to a drain. On the left side of the air-vessel a glass gauge, S, is fixed to show the extent to which the air is compressed when the ram is raising water to different heights. The gauge also enables an observation to be made as to the movement of the water inside the vessel at each beat of the dash-valve.

At T is a pressure-gauge by which can be computed the height to which the water is being raised when the ram is working. The delivery-pipe, U, empties into the cup at V. The stop-cock at W is for the purpose of throttling the delivery-pipe, so that the pressure-gauge will register a resistance equal to the height the water would be raised if the pipe was carried to a higher level than is shown in the drawing.

The water from the cup V runs into two measuring cylinders, X and Y, which are made out of pieces of lead soil-pipe. These cylinders are coupled together at the bottom, and have a stop-cock at Z. By this arrangement, when the water is being raised to a low level and a large quantity is being delivered, both the measuring cylinders can be used; but when the ram is sending the water up to a great height and only a small

quantity is being delivered, the cylinder X can be used singly.

The quantity of water contained in X is shown on the glass gauge A; the figures representing $\frac{1}{4}$ gals. The gauge shows $6\frac{1}{4}$ quarts of water in the cylinder X. When both cylinders are in use the figures on the gauge have to be doubled, to show the quantity of water contained in the two cylinders.

Three separate drive-pipes are shown in the drawing. That marked B is 60 ft. 4 in. long; that at C is 15 ft.; and that at D is 7 ft. 10 in. long. The drive-pipes are all 1 in., and the delivery-pipe $\frac{1}{2}$ in. in diameter. These sizes correspond with the connections to the ram.

The inlet ends of the pipes are slightly opened with a tan-pin, and the inner arris taken off with the view to reducing the friction of entry as much as possible.

The tank holds about 32 gals., measured above the inlet ends of the drive-pipes, and is 19 in. deep. The working head when the tank is kept filled, through a ball-valve, is 8 ft. 2 in., and when half empty, 7 ft. 4 in. These heights are measured above the centre of the inlet end of the body-pipe of the ram.

These particulars are given because a very large number of experiments have been carried out with the ram referred to, some of which will be dealt with in the following Chapter.

CHAPTER XI

Preliminary Experiments with the Drive-Pipes

BEFORE carrying out any experiments as to the actual duty to be obtained from the ram shown by Fig. 14, it was deemed advisable to make a few preliminary trials with the view to finding out the differences in the flow of water through the drive-pipes B, C, and D respectively. They were accordingly disconnected from the ram, and the time noted that it took to empty the cistern, which was filled to the 30·5 gal. mark. The pipes were afterwards connected, and the time noted that it took to run the same quantity of water through the ram when the dash-valve was held down.

The results are here given in tabular form :—

Drive-pipe.	Pipe plugged at the discharging end.		Pipe plugged in the cistern end.		Pipe connected to ram and dash-valve held down.	
	Mts.	Secs.	Mts.	Secs.	Mts.	Secs.
B	3	30	3	41	4	45
C	2	40	2	45	3	30
D	2	30	2	35	3	20

To compare the relative velocities of flow through each of the three pipes, the cistern holding 30·5 gals. :—

The pipe B emptied the water through the

ram in 4 minutes 45 seconds. It has already been shown that 1 ft. of 1-in. pipe contains ·034 gal. Then the velocity of flow $= \left(\frac{30·5 \text{ gals.}}{·034 \times 285 \text{ seconds}} = \right)$ 3·147 lineal feet per second, which is equal to a discharge of 6·42 gals. per minute.

The pipe C took 3 minutes 30 seconds, or 210 seconds, to empty the tank. This gives a velocity of 4·27 ft. per second, or 8·7 gals. per minute.

The pipe D was 200 seconds in emptying the tank. This gives a velocity of 4·48 ft. per second, and a discharge of 9 gals. per minute.

A further comparison can here be made as to what may be termed the 'striking force' of the water passing through each of the three pipes.

The pipe B is 60·3 ft. long, and holds 60·3 × ·34 lb. = 20·5 lb. of water. Flowing with a velocity of 3·147 ft. per second, the water strikes against the dash-valve with a force of 20·5 × 3·147 = 64·5 velocity-pounds on each circular inch of surface.

The water passing through pipe C strikes with a force of 15 ft. × ·34 lb. × 4·27 velocity = 21·77 velocity-pounds.

With the pipe D the striking force of the water = (7·33 ft. × ·34 lb. × 4·48 velocity =) 11·16 velocity-pounds.

Roughly speaking, the water passing through the pipe B exercises three times the force of that passing through C, and C has double the force of D.[1]

In practice the above values would not always be exactly as given, because the speed of flow of the water at the moment of impact with the dash-

[1] See also the remarks on page 44.

valve of the ram would in many cases be lower than stated in the various examples. The illustrations given, however, show the great advantage of a long drive-pipe over a short one, and emphasise the reasonings given in the Chapter on the length of drive-pipes.

PRELIMINARY EXPERIMENTS WITH AIR-VESSEL

The next trial experiments were made with the view of comparing the degree of air-compression in the air-vessel, as shown by the glass gauge indicated at S, Fig. 14, and the height to which the water was being raised by the ram, as registered by the pressure gauge shown at T in the same drawing.

EXPERIMENT I

With the drive-pipe D, and a head of water varying from 8′ 2″ to 6′ 6″ :—

Time of test in minutes.	Average head on drive in feet.	Beats of dash valve per minute.	Pressure gauge in lb.	Glass Gauge in inches.
1½	7ft. 4in.	148	2·5	Not visible
,,	,,	148	5·0	¾
,,	,,	148	8·0	2
,,	,,	132	10·0	3¼
,,	,,	113	17·0	5½

EXPERIMENT II

Continuation of last, but with a constant head of 8 ft. 2 in. :—

Time of test in minutes.	Head on drive-pipe in feet.	Beats of dash valve per minute.	Pressure gauge in lb.	Glass gauge in inches.
1½	8ft. 2in.	110	18·0	5¾
,,	,,	110	22·0	6½
,,	,,	110	28·0	7½
,,	,,	110	40·0	8¾
,,	,,	104	53·0	9⅝

Fig. 15 is a drawing of the ram air-vessel, and on the right-hand side is a diagram showing the compression curve of the air in the vessel under pressures extending from 1 to 5 atmospheres above the normal; one atmosphere of pressure being taken at 30 in. of mercury and at a temperature of 60° Fahr. Two atmospheres of pressure—

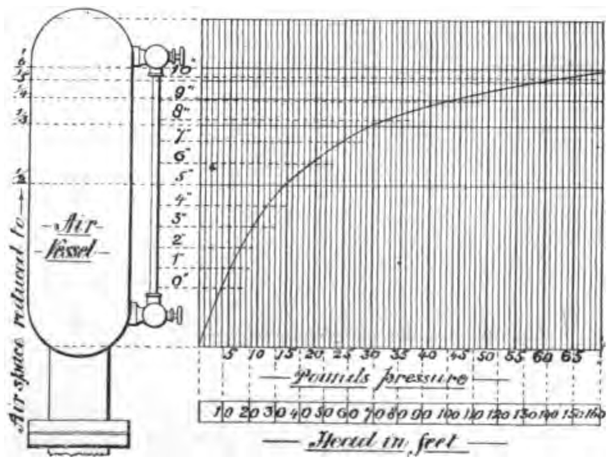

FIG. 15.

that is, one above the normal—reduces the air to half the space ; three atmospheres, or 2 above the normal, reduces the air to one-third the space ; and so on for other increases of pressure.

By the aid of the diagram the extent of the air compression in the vessel can be noted. The height to which the ram is raising water can also be seen at a glance, either by readings taken from the pressure gauge or by noting the level of the water in the glass gauge attached to the side of the vessel.

Also by the aid of the diagram any small mistakes made when taking observations are easily corrected, and intermediate readings found without having to make tedious arithmetical calculations.

CHAPTER XII

EXPERIMENTS TO FIND THE DUTY OF A RAM UNDER VARYING CONDITIONS

EXPERIMENT III

WITH the drive-pipe D (see Fig. 14) and with a flying start; that is, the records were not taken until the pressure gauge stood steady. Each test was timed to 4 minutes.

Water gauge in inches.	Pressure in lb.	Equivalent in feet.	Gallons raised.	Gallons used.	Gallons wasted.	Dash-valve beats per minute.	Head on drive-pipe in feet, average.	Efficiency or per cent. of duty.
0	4·0	9·2	5·33	13·33	8·0	150	7·00	53
$\frac{1}{8}$	7·5	17·2	5·66	16·00	10·34	150	„	86
$3\frac{1}{4}$	12·5	28·8	1·66	15·75	14·9	118	„	43
$6\frac{1}{2}$	22·5	51·8	·6	15·5	14·9	114	„	28
$7\frac{1}{2}$	28·0	64·5	·4	16·0	15·6	114	„	23
$7\frac{3}{4}$	29·0	66·8	·125	11·0	10·875	112	„	10
$8\frac{1}{4}$	34·0	78·3	·128	11·75	11·622	110	„	12

It should be noted that although the first two items show a like number of valve beats as having taken place in the same period of time, the second one gives a larger quantity of water both used and raised. The height of the delivery is also greater, and a higher percentage of duty thus obtained.

In these two experiments the dash-valve opened only a very short distance, but as the height of delivery was increased, the stroke lengthened, and when beating 112 and 110 strokes per minute, the valve opened to the full extent. But the force of the falling water was not sufficient to raise any considerable quantity when the height of the delivery was increased, as shown by the last two items.

EXPERIMENT IV

All as last, but with the drive-pipe B.

Water gauge in inches.	Pressure in lb.	Equivalent in feet.	Gallons raised.	Gallons used.	Gallons wasted.	Dash-valve beats per minute.	Head on drive-pipe in feet, average.	Efficiency or per cent. of duty.
0	4·0	9·2	5·137	14·136	9·0	28	7·00	47
1½	8·5	19·5	2·9	14·75	11·85	33	,,	54
3	12·0	27·6	1·8	14 0	12·2	36	,,	50
5	17·0	39·1	1·0	14·0	13·0	36	,,	40
6	20·5	47·2	·9	13·75	12·85	37	,,	44
6¾	24·0	55·3	·85	13·75	12·9	37	,,	48
7¼	26·5	61·0	·75	13·0	12·25	37	,,	50
8½	37·0	85·2	·575	12·5	11·925	36	,,	56
9½	47·5	109·4	·325	11·5	11·175	36	,,	43
9¾	53·0	122·1	·25	11·25	11·0	36	,,	38

The above Table, No. 4, shows a much more even series of results, both with regard to the valve beats, quantity of water used and also raised. With the long drive-pipe a considerable increase is found in the percentage of duty performed, and this is shown by a comparison of the tables. The reduction in the percentage of duty when water is being raised to great heights may be partially accounted for by assuming that air is an elastic,

and water a solid, fluid. When the vessel is filled with air the water forced through the delivery-valve meets with very little resistance, because the air is easily compressed to make room for it. But when the vessel is nearly filled with water, the air being tightly packed in the upper portion of the vessel, any incoming water is resisted by that above the delivery-valve, which is also pressed downwards by the compressed air. The water is also moving downwards in the air-vessel, and its motion has to be reversed against the pressure exerted by the elastic air. Force is thus partly expended in lifting the water into the air-vessel, and partly in reversing its direction of movement.

The next experiments were with a measured quantity of 28 gals. of water, and a varying head averaging 7·5 ft. on the drive-pipe.

Experiment V

With the drive-pipe D.

Duration of test.		Height raised in feet.	Gallons raised.	Beats of dash-valve per minute.	Efficiency or per cent. of duty.
Mts.	Secs.				
7	10	25	5·2	145	62
7	10	36	3·2	131	53
8	30	64	1·9	108	36
9	0	70	1·1	110	36
9	15	92	0·425	108	18

EXPERIMENT VI

With the drive-pipe C.

Duration of test.		Height raised in feet.	Gallons raised.	Beats of dash-valve per minute.	Efficiency or per cent. of duty.
Mts.	Secs.				
7	35	25	5·375	101	64
7	50	36	3·75	90	64
8	45	59	1·75	86	49
9	15	76	1·25	84	45
9	45	83	0·91	83	36
10	10	101	0·625	82	30

EXPERIMENT VII

With the drive-pipe B.

Duration of test.		Height raised in feet.	Gallons raised.	Beats of dash-valve per minute.	Efficiency or per cent. of duty.
Mts.	Secs.				
9	0	25	5·66	35	67
9	8	36	3·7	35	63
9	10	64	2·05	36	62
9	25	87	1·4	37	58
10	45	115	0·85	34	46

The whole of the experiments were carried out with the same ram and pipes, and no alterations were made to suit the varying heights to which the water was raised. The working conditions were the same throughout, with the exception of the lengths of the drive-pipes, and the adjustment of the stop-cock on the delivery-pipe.

A comparison of the experiments, as shown by the Tables V, VI, and VII, will again confirm

previous statements as to the necessity of having long drive-pipes, especially when the height to which the water is delivered is considerable.

It has already been shown that the percentage of useful effect of a ram decreases as the proportion of lift to fall increases. The following Table is based on Daubissan's rule for finding the efficiency of rams, which is $C = 1{\cdot}42 - ({\cdot}28\sqrt{h \div H})$, in which C is the percentage of useful effect; h is the height of the delivery in feet; and H = the head of the drive-water in feet.

$h \div$ H.	C.	$h \div$ H.	C.
4	·86	10	·53
5	·79	12	·49
6	·73	13	·45
7	·68	14	·41
8	·63	15	·37
9	·58	16	·30

If this Table is compared with the tabulated experiments Nos. V, VI, and VII, it will be found to give results which are much too high for the short pipes C and D, Fig. 14, but agree with many of the items based on experiments carried out with pipe B in the same figure and shown in Experiment VII. Hence, the Table is useless for ram problems unless the drive-pipe is of a suitable length.

ON FINDING PERCENTAGE OF DUTY OF A RAM

For the benefit of plumbing students, it may be here explained how the percentage of duty, as

given in the last columns of the foregoing Tables of Experiments, is calculated.

The power which works a hydraulic ram is the quantity of water that flows into it, multiplied into the height from which the water falls or flows. An example is taken from Table VII of the experiments. Twenty-eight gals. of water are used, and they flow from a height of 7·5 ft. Then 28 gals. × 7·5 ft. = 210 foot-gallons of flow-energy or power was exercised.

The useful effect was 5·66 gals. raised to a height of 25 ft. This gives 25 ft. × 5·66 gals. = 141·5 foot-gallons of water raised. By dividing the useful effect by the energy exerted the duty is ascertained.

$$\text{Thus } \frac{141 \cdot 5}{210} = \cdot 67, \text{ or } \frac{67}{100} = 67 \text{ per cent.}$$

Stated concisely the problem would be

$$\frac{5 \cdot 66 \times 25}{28 \times 7 \cdot 5} = \cdot 67$$

or 67 parts out of every hundred of energy usefully exerted, the remainder being absorbed by, or contained in, the machine and the water inside.

The remaining 33 parts are not by any means wasted, but are doing duty to the utmost extent.

A portion is required for lifting and suddenly closing the dash-valve. Another portion is necessary for lifting the delivery-valve, inside the air-vessel, and the water above it, and also in still further compressing the air in the upper part. The energy exercised in compressing the air is transmitted to the water in the delivery-pipe to keep it

in motion between the beats of the dash-valve. A further portion of the 33 parts is absorbed by friction of the water in the pipes, and a considerable part is required to reverse the direction in which the water is travelling in the drive-pipe. If this water does not reflow the dash-valve will not open, but will be held up to its seating, and thus stop the action of the ram.

Again, the further the water is driven back the greater the force with which it returns. With a short drive-pipe the water can return but a short distance, so that the intervals between the change of direction of flow are very small. The practical experiments also show that there is a great difference in the number of strokes per minute between the three pipes which were used. There is also more waste with the short pipe. The reason for this is obvious, because the dash-valve opens three to four more times than with the long drive-pipe.

The experiments have also shown that with the short drive-pipe the increase in height to which the water is being raised results in a decrease in the number of beats per minute of the dash-valve and also in the quantity of water raised. With the longer drive-pipes the results are more even.

CHAPTER XIII

Rules for Finding the Working Capacity of a Ram

To state the rules concisely and avoid long written descriptions, assume that:—

Q = quantity of water used in gallons.
q = quantity of water raised in gallons.
H = head on drive-pipe in feet.
h = height to which delivered in feet.

$$\text{Then } Q = \frac{q \times h}{H} \qquad H = \frac{q \times h}{Q}$$

$$q = \frac{Q \times H}{h} \qquad h = \frac{Q \times H}{q}$$

To explain the first formula in words:—

The quantity of water necessary to work a ram is equal to the quantity raised multiplied by the height to which raised, and divided by the head on the drive-pipe; the height and head being in feet, and the quantities used and delivered being in gallons.

Example I

Find the quantity of water necessary to raise 10 gals. to a height of 50 ft., the surface of the water in the drive-tank being 6 ft. above the ram.

$$\text{Then } Q = \frac{10 \times 50}{6} = 83{\cdot}3 \text{ gals.}$$

For rough approximation, allow one-third more for friction and excess of power over work, and this gives a total of

$$\frac{83{\cdot}3 \times 4}{3} = 111 \text{ gals.}$$

as the actual quantity necessary.

EXAMPLE II.—To find H

$$\text{If } Q = 50$$
$$q = 6$$
$$h = 30$$
$$\text{Then } H = \frac{6 \times 30}{50} = 3{\cdot}6.$$

To which add one-third $= \frac{3{\cdot}6 \times 4}{3} = 4{\cdot}8$ ft. head on drive-pipe.

EXAMPLE III.—To find q

$$\text{When } Q = 40$$
$$H = 6$$
$$h = 60$$
$$\text{Then } q = \frac{40 \times 6}{60} = 4 \text{ gals.}$$

In this case one-third must be deducted from the results; and this gives $\frac{4 \times 2}{3} = 2{\cdot}66$ gals. the actual quantity raised.

EXAMPLE IV.—To find h

When $Q = 60$
$H = 10$
$q = 5$

$$\text{Then } h = \frac{60 \times 10}{5} = 120 \text{ ft.}$$

In this case, too, one-third must be deducted which gives $\frac{120 \times 2}{3} =$ 80 ft. the height to which the water would be raised.

In the above calculations no time for doing the work was mentioned, and neither is it necessary, as the time during which the power is being exerted equals that in which the actual results are obtained.

In the foregoing random examples a constant of one-third of the quantity was taken as an allowance for excess of power over load, &c., in all cases. But by studying the results in Experiment VII, the percentage of so-called loss is found to vary from 33 to 54, thus showing that one-third the value would not apply under all conditions with regard to the quantity of water either used or raised, or for variations in the height of feed or delivery.

If the results given in Table VII are dealt with, and the lowest is deducted from the highest, this gives $67 - 46 = 21$ difference in the percentage of useful effect; and if the lowest is deducted from the highest height raised this gives $115 - 25 = 90$ ft.

$$\text{Thus } \frac{90}{21} = 4{\cdot}2.$$

From this it may be assumed that an approximate loss of 1 per cent. is due to every increase of

4·2 ft. in the height to which the water is raised when the data based on the results shown by experiment in Table VII are used.

To find the Necessary Lengths of Drive-pipes so that each of the Experiments in Table VII showed the same Efficiency as the First One

The pipe was 60 ft. long, and with varying conditions gave an efficiency of 67, 63, 62, 58, and 46 respectively. Although it is the quantity or weight of water that gives the impulse, that need not be taken into the calculations, because the length of pipe represents the comparative proportion of water necessary to do the required work.

Then proceed as follows by ordinary rule of three:—

As 63 per cent. : 60 ft. :: 67 per cent. : 63·8 ft. —the length of drive-pipe necessary for gaining the same percentage of duty for the second as for the first in the Table.

For the third experiment, by the same reasoning:—

$$\frac{60 \times 67}{62} = 65 \text{ ft. nearly.}$$

For the fourth experiment—

$$\frac{60 \times 67}{58} = 70 \text{ ft. nearly.}$$

And for the last in the Table—

$$\frac{60 \times 67}{46} = 88 \text{ ft. nearly.*}$$

* These calculations and those on pages 69 and 70 are only approximately correct.—AUTHOR.

Although a drive-pipe 60 ft. in length was taken as a basis for the foregoing workings, it should be clearly understood that it is not an ideal length, or the length of pipe that should be used for a ram under any and all conditions. On the contrary, it may be considered as a minimum length for low lifts. For high lifts the working rules given on page 45 would give far better results.

By lengthening the drive-pipe there is an increase of friction of the inside water, and the length of stroke is increased. The longer column of moving water would occupy more time in reversing the direction of its flow, resulting in slower beats of the dash-valve. But the ultimate results would be about the same as worked out theoretically above.

When work or resistance is increased the power to overcome it must also be increased.

Having dealt with increase of power by lengthening the drive-pipe, it will now be shown that the same object can be obtained by raising the height of the drive-tank.

In the preceding examples the height of the feed-water surface was 7·5 ft. above the ram, and (from Table VII) raised a portion to a height of 25 ft., developing an efficiency of 67 per cent. By the same reasoning as was used for the drive-pipe length—

$$\frac{7{\cdot}5 \times 67}{63} = 8 \text{ ft. nearly,}$$

the height the water in the drive-tank should be for the second experiment.

For the third—

$$\frac{7{\cdot}5 \times 67}{62} = 8{\cdot}1 \text{ ft.}$$

For the fourth—

$$\frac{7{\cdot}5 \times 67}{58} = 9 \text{ ft. nearly.}$$

And for the last—

$$\frac{7{\cdot}5 \times 67}{46} = 11 \text{ ft. nearly.}$$

Referring again to the length of the drive-pipes, the calculations were based on a ram capable of doing the work which was required. Other size rams could be used to give approximately the same results. But if they were larger then the drive-pipes could be shorter, but the diameters should be proportionate to the ram. In working out such problems the following table of capacities of pipes will be found useful :—

TABLE OF CAPACITIES OF DIFFERENT SIZE PIPES

Internal diameter of pipe in inches.	Contents in gallons per foot lineal.	Weight of water in lb. per foot lineal.
¾	·019	·19
1	·034	·34
1¼	·053	·53
1½	·076	·76
2	·136	1.36
3	·306	3·06
4	·544	5·44
5	·852	8·52
6	1·224	12·24

If a pipe holds a given number of gallons, a larger one holding the same quantity is shorter in length.

Taking the pipe which was 87·4 ft. long, the Table shows that a 1-in. pipe holds ·034 gal. per foot, and $\cdot034 \times 87\cdot4 = 2\cdot9716$ gals.

A $1\frac{1}{2}$-in. pipe to hold the same quantity =

$$\frac{2\cdot9716}{\cdot076} = 39 \text{ ft. long.}$$

With a ram constructed to work with a $1\frac{1}{2}$-in. pipe, the latter length would enable it to raise as much water as the smaller ram worked with a 1-in. pipe, 87·4 ft. long, other conditions being equal.

To show this, assume 8 ft. head :—

Then $8 \times 1^2 \times \cdot034 \times 87\cdot5 = 23\cdot8$ ft.-gals. of flow energy.

And $8 \times 1\cdot5^2 \times \cdot034 \times 39 = 23\cdot86$ ft.-gals., or approximately the same power.

But the larger size pipe would not give the same results with the smaller ram for reasons that have been before explained.

Results obtained by a Maker of Rams

The writer has recently had some correspondence with the makers of the experimental ram used by him, and they have given him a few results obtained by the firm in actual practice. These results further emphasise previous remarks as to the value of long drive-pipes.

Their results are as follows :—

With an 'A' or small-size ram fitted with 66 yds. (or 198 ft.) of 1-in. lead drive-pipe, 15-ft. fall, $2\frac{1}{3}$ gals. supply per minute, 700 gals. were

raised in 24 hours to a height of 65 ft. above the ram through 250 yds. of ¾-in. pipe. This gives :—

$$\frac{700 \times 63}{2\frac{1}{3} \times 60 \times 24 \times 15} = \cdot 9$$

or 90 per cent. of effective duty.

With 'B' size ram, fitted with 50 yds. (or 150 ft.) of 2-in. drive-pipe, 6-ft. fall, 6 gals. supply per minute, 700 gals. were raised per 24 hours 63 ft. above the ram through one mile of 2-in. delivery-pipe.

This ram gave :—

$$\frac{700 \times 65}{6 \times 60 \times 24 \times 6} = \cdot 85$$

or 85 per cent. of effective duty.

With a 'C' size ram, with 112 ft. of 3-in. pipe, 8-ft. fall, and 14,000 gals. supply per 24 hours, 2,000 gals. were raised 42 ft. above the ram.

Then for this case we have :—

$$\frac{2000 \times 42}{14000 \times 8} = \cdot 75$$

or 75 per cent. of effective duty.

The water-supply to this latter ram was not entirely satisfactory, and varied considerably. Eventually it became so reduced that it was found necessary to fix a smaller size dash-valve when the percentage of effective duty rose to 81.

The makers also draw attention to the lengths of the above drive-pipes, which varied in length from two to three times the vertical height to which the water was raised. They also mention that it is difficult to formulate any rules for rams, and that every case has to be considered separately.

Having so far given the principles upon which

calculations are made, and explained that to do a certain amount of work the drive-pipe must not be less than a given size and length, it now remains to explain that the other extreme must not be gone to.

DRIVE-PIPES SHOULD NOT BE TOO LONG

If the drive-pipe is too long, the energy of the larger volume of water is so much increased that, in the absence of adequate resistance or work to be done, the ram is seriously injured by the excessive shock.

The writer had such a case, in which the delivery-valve inside the air-vessel was constantly breaking, and every few days a new one was necessary. The drive-pipe was 4 in. in diameter and 300 ft. long, and capable of raising a large quantity of water to a height of over 200 ft. The actual height required was only about half that to a mansion about three-quarters of a mile distant.

By fixing a square head stop-cock in the delivery-pipe, near the ram, and closing it until a temporary pressure-gauge registered the desired resistance, the ram was made to work satisfactorily in so far as giving an ample supply of water without any of the working parts or valves being broken by the shock of the drive-water.

In another case, in which the drive-pipe was 300 yards long and 6 in. in diameter, the pipes frequently burst, and it was found that ordinary cast-iron would not resist the shock of the water inside. To relieve this a stand-pipe was fixed about midway between the ram and feed-tank, so that a portion of the force of the moving water was spent

in pushing a quantity up the stand-pipe each time the dash-valve closed.

To explain this, assume Fig. 16 to be a sketch of the arrangements, the water flowing from the tank E to the ram F. Without the stand-pipe G, the whole of the force is expended on F. But with the stand-pipe, when the dash-valve closes a portion only of the force is expended on F and the remainder in pushing the water up G, as shown by the bent arrow. Approximately about one-third of the force of the moving water is thus taken off F.

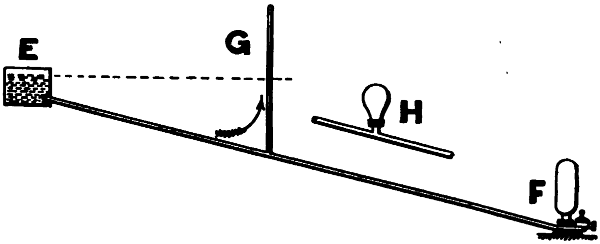

FIG. 16.

The stand-pipe was continued above the level of the feed-tank, otherwise water would have been forced out of the top end. Similar results would have been obtained if a large-size air-vessel had been fixed, as shown by H, Fig. 16.

In the above cases there was a waste of power and money was ill-spent, not only in the first cost but in the additional outlay for disposing in a useless manner of the excess of force or power.

Neither should the feed tank be at too great a height above the ram, because this would lead to excessive shock and have an injurious effect on the materials used for the ram and pipes.

CHAPTER XIV

Dash-valves and their Action

Many ram-makers have given the dash-valve a considerable amount of thought, and on searching through the Patent Office records a variety of forms are found to have been patented from time to time.

Fig. 17 is an ordinary dash-valve made on the old Bramah pattern. The outlet orifice has about the same diameter as the inlet to the body-pipe. The length of the stroke, which gives the height of the opening between the valve and the seating, or the free waterway, is regulated by fixing washers on the spindle, as shown at I.

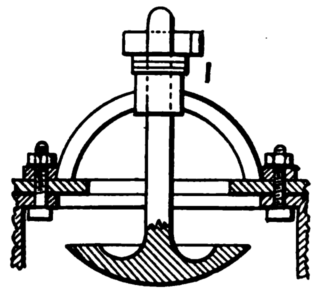

Fig. 17.

Fig. 18 is a sketch of a patented ram in which the dash-valve, shown by the dotted lines inside the body at J, is fixed on a pendulum, K, with a counterbalance, L. A modification of the same patent has a spring with adjusting screws at M, instead of the hinged joint and counterbalance.

Either of these would have a tendency to open the valve and push back the drive-water.

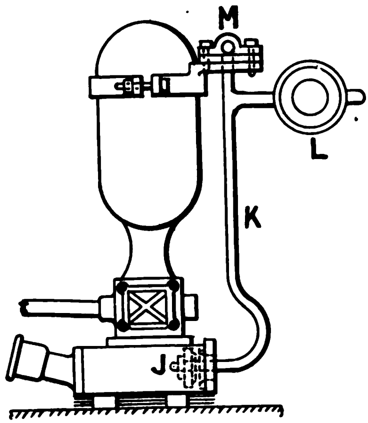

FIG. 18.

Fig. 19 is a detail of another patent, in which the dash-valve has a rubber ring at N. When the valve dashes up against the seating, O, there is little doubt the 'spring' of the rubber acts a part in causing the drive-water to be reversed in its direction. The dash-valve works in a cylinder, and doubtless economises the water, because very little can escape without doing duty.

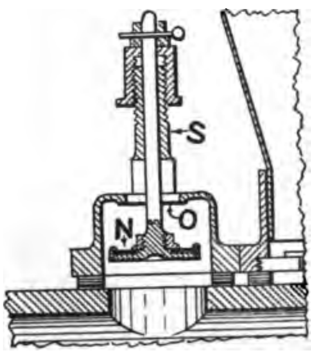

FIG. 19.

Fig. 20 is an enlarged section of the dash-valve

in the ram shown by Fig. 14. This valve also works in a cylinder, P, and has a copper disc, Q, carefully fitted, so that the whole of the force of the water is utilised without unnecessary waste. The butterfly nut, R, has the blades fixed obliquely, so that the passing water imparts a slight rotary motion to the valve and thus prevents the face of the latter, or of the seating, being unevenly worn. The beats of this valve and the lengths of the strokes regulate themselves according to the power exerted, as was shown by the tabulated experimental results that were dealt with in a previous Chapter.

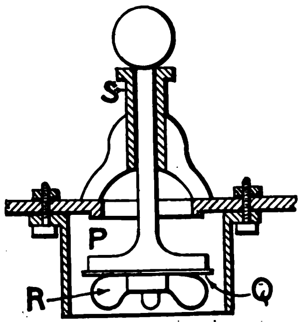

FIG. 20.

Fig. 21 is another section of a dash-valve in a patented ram which also works in a cylinder.

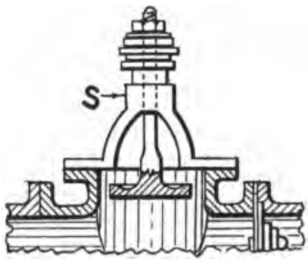

FIG. 21.

All the valves shown by Figs. 19, 20, and 21 are far better than that shown by Fig. 17. The latter is heavy and massive, and, by reason of its weight, requires a considerable amount of force to lift it up to its seating. The spindles

too, in Figs. 19, 20, and 21 slide up and down in the guides shown at S.

The dash-valves of hydraulic rams should always be as light as possible, and only just strong enough to resist being broken by the shock caused by the water.

For large-size rams one patentee has a counter-balance or weight on the outside of the dash-valve casing. The spindle of the dash-valve is connected by a special joint to the end of a lever mounted on an axis. The other end of the lever is loaded with a weight, which can be moved on the lever so as to about balance the valve, and is secured in the desired position by a set-screw.

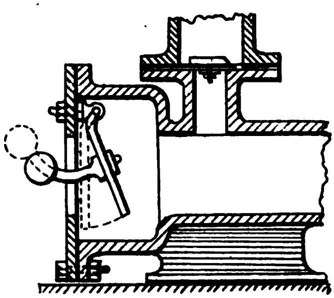

FIG. 22.

Fig. 22 is a dash-valve suitable for a ram of the description shown by Fig. 3. This ram and that shown by Fig. 18 have something in common, in that they are so balanced and adjusted that they open and close by the least backward or forward motion of the water in the drive-pipe.

CAUSE OF RE-FLOW OF WATER IN DRIVE-PIPE

There is a great difference of opinion as to the cause of the current of the drive-water reversing when the dash-valve closes. By some it is held that water is elastic and rebounds much in the

same manner as an indiarubber ball would. That this is not so is evidenced by breakages that take place in water-pipes by what is known as water-hammer. If water was elastic, the loud noises made in a service-pipe when a bib-cock is suddenly closed would not be heard, and an elastic medium such as air confined in a chamber, would not be necessary for preventing it.

Another example is found in the philosophical appliances shown by Fig. 23, and known as water-hammers. These are made of glass and are about half filled with water. The other half has the air exhausted, the remaining space being known as a vacuum. By holding either one of them upright, and smartly raising and then lowering it, the water is jerked upwards, and on falling makes a noise as if two solid bodies had knocked together.

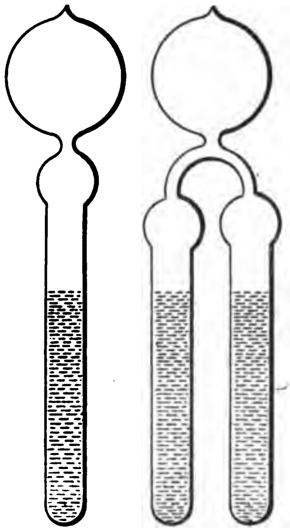

FIG. 23.

Or if held with the bulb downwards until all the water has run into that end, and then suddenly reversing the instrument and holding it close to the ear, the water trickling into the straight tubes makes a noise similar to pebbles falling on to something hard. This would not be so if water was elastic. The water, however, contains air to

a certain extent. Ordinary spring water is compressed by about $\frac{1}{20000}$ part of its volume by one atmosphere of pressure; and because water is porous, it follows that the pores may be filled with gases of some kind or other, and these gases are compressible.

The materials of which the ram is made are also slightly flexible, and 'give' with the force of the water, and on returning to their original form help to push the water back.

If a volume of air was inside the body-pipe the full force of the water would not be utilised, and a less quantity would be raised by the ram owing to the air acting as a spring buffer.

The dash-valve shown by Fig. 19 has an india-rubber washer on the valve, and no doubt the flexibility of the washer causes a slight rebound of the valve which reacts on the water beneath it.

When making exact (or as nearly exact as possible) calculations on the duty done by pumps, an allowance has to be made for what is known as 'slip,' or the small quantity of water that returns into the suction-pipe when the sucker-valve is in the act of closing. When the delivery-valve inside the air-vessel of a ram is in the act of closing, a small quantity of water is pushed back into the body-pipe, and this, although small, probably helps to start a backward motion in the drive-water.

One ram-maker has a patent for the appliance shown by Fig. 24. To aid the reflux action of the drive-water, a small chamber, T, has a valve over the opening, U, in the body-pipe. This valve fits tightly, but is free to slide up and down. Over the valve is a spring and adjusting screw for pressing the valve downwards.

When the dash-valve closes by the momentum of the feed-water, part of the force is exerted in pushing some of the water through the delivery-valve, V, and at the same instant of time the valve T is pushed upwards and compresses the spring W.

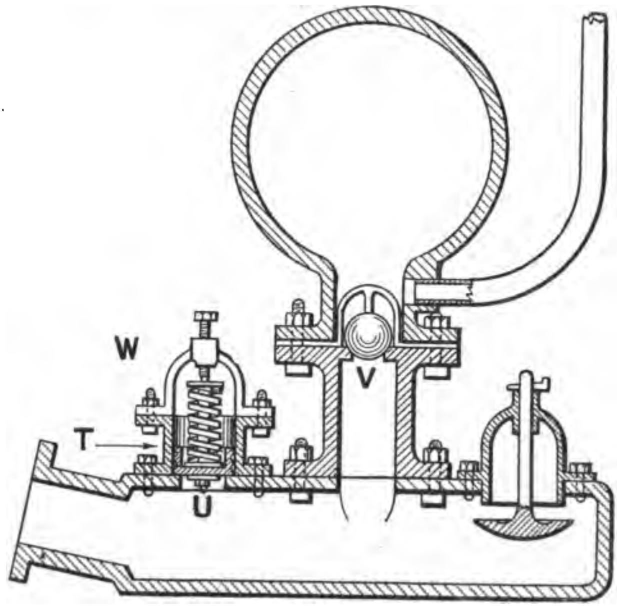

FIG. 24.

As soon as the full force of the feed-water is expended, the spring pushes the valve T down and causes the current of drive-water to be reversed, when the whole of the action is repeated.

The same maker has other patents, in which what may be termed the seating of the dash-valve

has a concave or hollow surface, and is perforated with several holes for the water to pass through. A short distance away from the seating is an indiarubber band, in some cases indiarubber discs, which is, or are, forced against the seating by the momentum of the water. The indiarubber is stretched in doing this, and on returning to its ordinary degree of tension causes a slight reflux action in the direction of the flow of the drive-water.

Another patented ram has a spring fixed outside the discharging outlet, so that the spindle of the dash-valve knocks against it. The spring acts similarly to a person's finger pressing on the spindle, and thus pushes it down and re-opens the valve. The use of this spring is claimed for another purpose, but doubtless could be made to answer for that suggested.

Any or all of the foregoing details have an influence in causing a reflux action of the water in the drive-pipe to a hydraulic ram. The reflux action of the water in a drive-pipe is small, but nevertheless plainly discernible at the entry end of the drive-pipe. If there were no backward motion of the water, the dash-valve would not open. The weight of the valve alone is not sufficient to open it, and it will remain closed if held up to its seating until all motion in the water has ceased. Neither should the valve be so heavy as to open by its weight. On the contrary, it should be as light as possible for reasons before stated.

As soon as the backward momentum of the water in the drive-pipe has been overcome by the pressure from the drive-tank, a forward motion takes place. The motion is slow at first and gradually increases in speed, but the highest velocity

due to the head is not attained. When the speed is sufficient to dash the valve on to its seating, the motion of the water is again reversed and the whole proceedings are repeated.

Finally, it is important that the water throughout the length of the drive-pipe should reflow after each stroke of the dash-valve; otherwise the whole length of the moving column of water, when flowing downwards, would not be exerted in pushing some of the water through the delivery-valve at each pulsation of the dash-valve. The evils of air, of sharp elbows or turns in the pipe, and of roughness and obstructions inside the pipes have already been referred to.

Delivery-valves of Rams

Delivery-valves are those fixed on the body of the ram at the bottom of the neck of the air-vessel, and through which a portion of the water is pushed at each stroke of the dash-valve. Amongst the earliest made, and used by some makers at the present time, are those known as 'spherical' valves, which consist of gunmetal balls with seatings, as shown at V, Fig. 24. These have a cage for preventing the ball rising too high or being dislodged from its position.

Fig. 25 is another kind which has an india-rubber seating at X, and a spindle with a guide-bar and nut at Y.

Another valve is shown by Fig. 26. This is a 'ground-in' gunmetal valve, Z, with 'feather guides' and a 'stop' and regulating screw, A, for preventing the valve rising too high or jumping out of its position.

The delivery-valve to the patent ram, of which Fig. 19 is the dash-valve, is shown by Fig. 27. In the figure B, B are perforations in a brass seating,

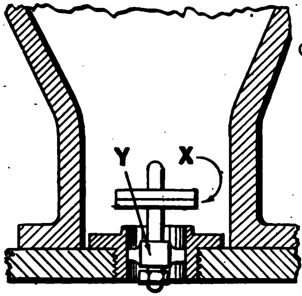

FIG. 25.

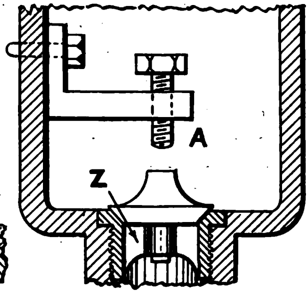

FIG. 26.

and C is a rubber disc with cap and spindle. The object of this form of valve is to get as large a waterway as possible without the valve rising too high, and the consequent loss of water by 'slip.'

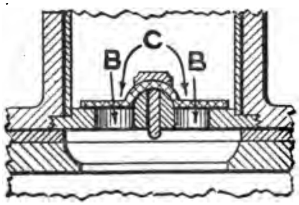

FIG. 27.

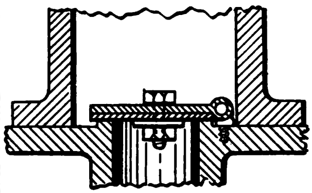

FIG. 28.

'Slip,' however, helps to cause a reflux action of the water in the drive-pipe, as was mentioned on a previous page.

Another delivery-valve, which forms a part of two or three patents, is shown by Fig. 28. This is simply a valve hinged on one side.

As a rule most makers have the delivery-valves of a good size for reasons above given. In some cases the waterways are equal, but in others the diameters are only about half that of the drive-pipes.

With small-size rams access to the delivery-valves is obtained by unbolting and removing the air-vessels, but with large rams having very heavy air-vessels this is inconvenient, and access-doors or removable plates over side-openings are provided for the purpose.

One such door or access-plate is shown on the base of the air-vessel, Fig. 18.

CHAPTER XV

AIR-CHAMBERS OR AIR-VESSELS

WITH regard to the proper sizes of air-vessels, the ordinary rule is that 'the capacity of the latter should be equal to the contents of the delivery-pipe.' But this is impracticable, because one pipe may be 100 yards long and another a mile or upwards, so that each ram would require a special-sized chamber.

A better rule would be :—The contents of the air-vessel should be equal to twice the contents of the delivery-pipe, whose length is equal to the vertical height to which the water is raised; an average being taken so that one size of vessel would be about right for each size of ram when fixed under various conditions.

Some makers have twin air-vessels to their rams, so as to double the air capacity.

Other makers have two air-vessels on the same body-pipe, and a sluice-valve between each vessel and the body-pipe, so that if one vessel had the air exhausted it could be shut off and recharged with air without stopping the ram working.

An air-vessel eventually becomes exhausted of air. This is due to the water absorbing the air. When this occurs an enormous strain is brought to bear upon the ram, and its efficiency is lowered.

Without air, and the vessel 'water-logged,' the whole of the water in the delivery-pipe 'stops and starts' with each pulsation of the working or dash-valve. Whereas with a properly-charged air-vessel the water in the delivery-pipe is in motion the whole of the time the ram is working, and travels at only about one half the speed, with a consequent reduction of friction. When the water is motionless between the strokes, a great deal of the applied power is occupied in overcoming the inertia of the water in the delivery-pipe and starting it into motion.

Not only is the ram robbed of a portion of its efficiency, but where the water is forced directly into a tank or cistern in an inhabited house, with a water-logged air-vessel the noises made by the beats of the dash-valve are increased, and can be distinctly heard in the house. Because of these noises, complaints have been made that the people could not sleep during the night-time.

In one case the noise was so serious that the writer, to sever the metallic connection of the iron pipe with the ram, had a piece of indiarubber tubing especially made for the purpose, and bound outside with copper wire to resist being burst by the internal pressure. This tube was fixed near the ram, a portion of the delivery-pipe being removed for the purpose.

Although the rubber tube reduced the noise considerably, it was still heard in the house, and the conclusion was come to that water itself is a good conductor of sound.

In the same mansion another complaint was made of the noise of the water trickling down the cistern overflow-pipe. The pipe was fixed inside

the house so as not to be affected by frost in the winter time. For the foregoing reasons the writer considers it inadvisable for a ram to deliver the water directly into a house, unless there is an isolated wing in which the cisterns and pipes can be fixed. The water from the ram should be sent into a reservoir or a water-tower, from which it can gravitate or flow to the house or premises.

The loss of air out of the vessels is a troublesome problem, and a considerable amount of thought has been given with the view to overcoming the difficulty.

One ram specialist has invented a substitute for the air-vessel, as shown by Fig. 29, consisting of a hollow cylinder, with a solid end, inverted in a second cylinder fixed over the delivery-valve. The inverted cylinder is held down by springs, and slides inside the other one, a special provision being made to render the joint watertight between the two. At each pulsation of the dash-valve the water that is forced through the delivery-valve causes the sliding cylinder to rise; the action of the springs then slowly forces it down again and expels the water into the delivery-pipe.

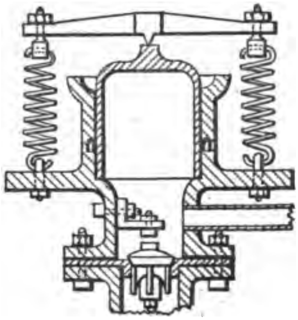

FIG. 29.

For prevention of loss of air out of the vessels it has been suggested that sperm oil, glycerine, or other suitable liquid poured into the vessel would

float on the surface of the water and prevent contact with the contained air. The writer has no knowledge of the results, or whether the water was thus rendered unfit for domestic purposes.

Another suggestion was to have the air-vessel in two halves and bolt a flexible indiarubber diaphragm between the flanges, so that the air and water were not in contact. Fig. 30 is drawn to show the arrangements.

Many devices have been invented for supplying he necessary quantity of air to the vessel. One of

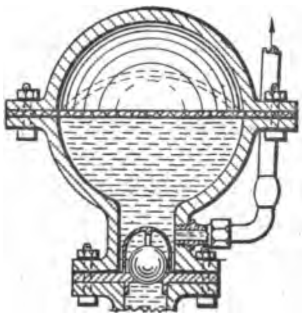

FIG. 30.

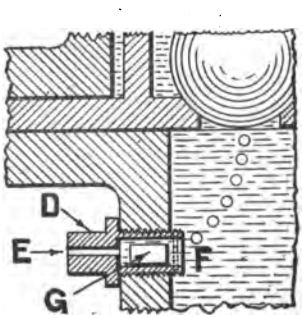

FIG. 31.

the earliest was known as the 'sniff' or 'sniffle' valve, sometimes called the 'snorter.' This is shown in section at D, Fig. 31, and is screwed into the side of the trunk leading from the body-pipe to the air-vessel just below the delivery-valve. At E is a small hole about the size of a pin, F being the end screwed into the trunk. The small piston, G, is loose, and free to slide to and fro, a stop-pin being fitted as shown by the double dotted line;

When the dash-valve closes, the water that forces open the delivery-valve acts also on G, and drives it towards the inlet E. When the water reflows in the drive-pipe the valve is drawn back and a small quantity of air enters through the hole E, and bubbles upwards, as shown by the small circles. These air-bubbles are carried with the next rush of water through the delivery-valve into the air-vessel, and this is repeated at each beat of the working-valve.

Fig. 32 is a side view illustrating the principles of another air-valve. The screwed end is fixed in the ram body-pipe, the end being open for the water to enter. When the dash-valve closes, the water is forced against a flexible cup, shown by double dotted line at H, the air on the opposite side and in I being expelled through a valve at J and the pipe K, which is connected to the air-vessel above the delivery-valve. Another valve at L acts similar to the sucker-valve of a pump. Air enters through this valve to fill the body I when the flexible diaphragm H is drawn back by the reflux of the drive-water to the ram. By this arrangement a small quantity of air is pumped, or forced, into the chamber at each stroke of the dash-valve.

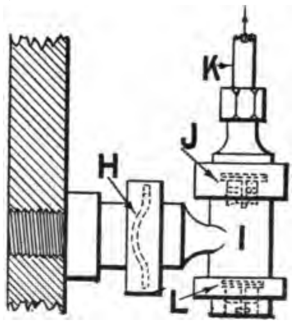

FIG. 32.

There are other patented sniff-valves which work similar to the last one, but have a piston

with a cup-leather instead of the indiarubber, and a spring to aid the reflow of the water for drawing air through L into the chamber I. These are literally air-pumps, but it is not necessary to illustrate them, as the principles are so very similar to those shown by Fig. 32. Hollow indiarubber balls have been suggested for placing in air-vessels. Air-pumps to be worked by hand for recharging the air-vessels have also been proposed, but the writer has never seen these appliances in actual use.

CHAPTER XVI

Pumping and Double-action Rams

In many parts of the country the problem of supplying mansions with potable water presents great difficulties. The quantity may be unlimited, but the quality not at all suitable. Or a limited quantity of good quality may be available, but not nearly sufficient to work a hydraulic ram. In the case of a small supply of good water and a plentiful supply of another kind, which would not be suitable for domestic purposes, being available, and where circumstances are favourable, a specially constructed ram can be used and worked by the uusuitable water to raise that which is good.

Fig. 33 is a section of such a patented appliance. In the drawing, M is the body-pipe to an ordinary ram, the dash-valve of which was shown by Fig. 19 and the delivery-valve by Fig. 27. N is a continuation of the body-pipe, and O is an indiarubber diaphragm, the edges of which are securely fixed between two flanges so that no water can escape either from below, upwards, or *vice versâ*. P is an inlet-valve over the end of what may be called the suction-pipe, which is continued to a well or clean water reservoir. At Q is a valve opening upwards into an air-vessel similar to the other one shown

at R, whence a pipe leads to the storage cistern or reservoir.

The action is as follows: Impure water entering

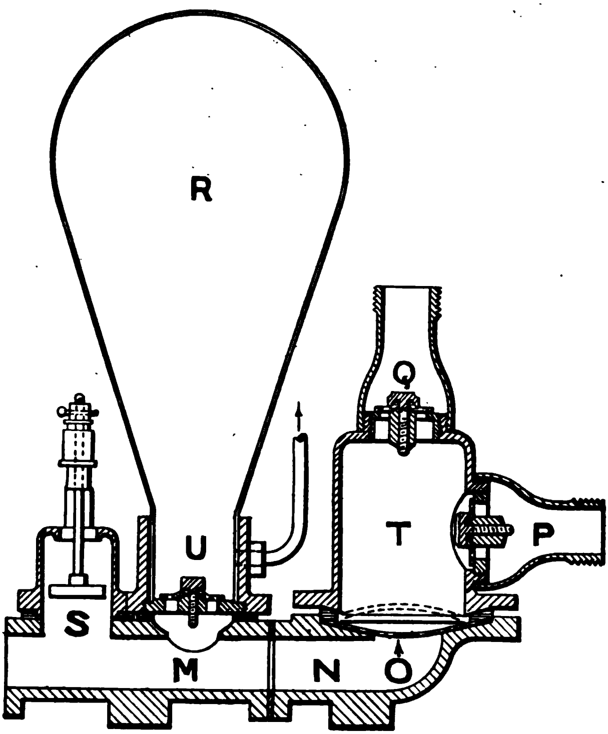

FIG. 33.

the body-pipe, M, escapes out of the dash-valve, S, which is open. The flow of water dashes the valve up to its seating. The water no longer flows freely

away, having had its escape suddenly arrested, and the impetus is expended on the under side of the diaphragm, O, which is pushed upwards and forces the water contained in T through the valve, Q, into the air-vessel and the delivery-pipe above it.

When the reflow of the drive-water takes place, the diaphragm, O, is drawn downwards, and leaves a vacuum in T, which is filled with pure water through the valve, P, from the well or spring. These actions are continuous so long as the ram is at work and the water-supply sufficient.

The two waters are separate and cannot mix, nor can the dirty water be sent up to the mansion so long as the diaphragm is in good condition and free from defects.

The air-vessel, R, and valve, U, can be omitted, but if it is desired to send the foul water for using in a farmstead or garden, it should be retained and the necessary delivery-pipe attached.

The two parts of the ram are bolted together by means of flanges. But if it is desired for the ram to be single-acting, so that only a portion of the water which works it is raised, the parts N, T are omitted, and a blank flange bolted on to the open end between M and N.

When used as a pumping ram only, the whole force of the drive-water is expended on O, but when used as a double ram, so that clean and foul water are both raised to their respective positions, the force is divided, part being expended on O, and the other portion in pushing water through the delivery-valve, U. In other words, if a single-action ram was capable of raising 1,000 gals. per day, the double ram would raise nearly the same quantity, but half would be foul and half clean

water; and these two kinds of water would be delivered in opposite directions, or to wherever the pipes were fixed.

The pumping ram will raise water from about the same depth as an ordinary pump, and the distance should never exceed 25 ft. in vertical height between the water and valve, P. With a lesser height better results are obtained.

With the pumping ram shown by Fig. 33 the force of the drive-water is divided, one portion of the force being expended in forcing water through the delivery-valve U, and the other portion in forcing water through the delivery-valve Q. The combined quantities of water thus raised are a little less than would be delivered by an ordinary single-acting ram.

Another pumping ram is shown by Fig. 34. A speciality in this case is that it is impossible for the two waters to mix. This is a pumping ram only, and does not raise any portion of the water that works it, but only that which it is desired to store for use.

To describe the appliance:—V is the inlet and W the dash-valve, similar to those of an ordinary ram; G is a watertight piston working in a cylinder, and having a rod, Y, to connect to a second and smaller piston in the cylinder, X, the piston being pushed downwards by the compression spring, Z. The air-vessel, A, has a delivery-valve, B, at the bottom, and over the body-pipe, C. A sucker-valve with stop is fixed at D over the suction-pipe, E, and F is the delivery-pipe leading to a cistern or storage tank.

The action is as follows:—The unsuitable water entering at V escapes at W until an attained

velocity suddenly closes the valve, when the force is expended on the bottom of the piston, G. This raises also the piston X, and forces clean water out of C through the delivery-valve B into the air-vessel, and thence to the storage cistern.

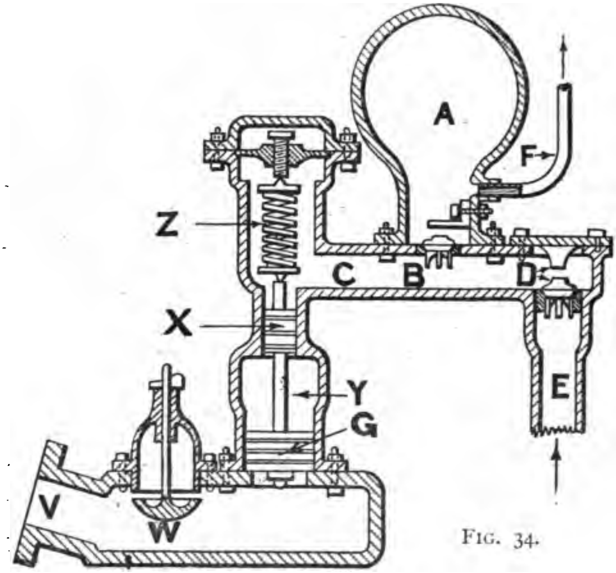

FIG. 34.

As soon as the force of the drive-water is expended, the spring, Z, presses down the pistons, and leaves a vacuum in C, which is again filled with pure water through the sucker-valve and pipe, D and E.

The water is raised by what is really a force-pump, with a solid piston or plunger adapted to work automatically by the shock of flowing water.

Another ram specialist has patented a pumping ram, as shown by Fig. 35. The dash-valve is not shown in the figure, as it is behind the parts illustrated. The form of this dash-valve was shown by

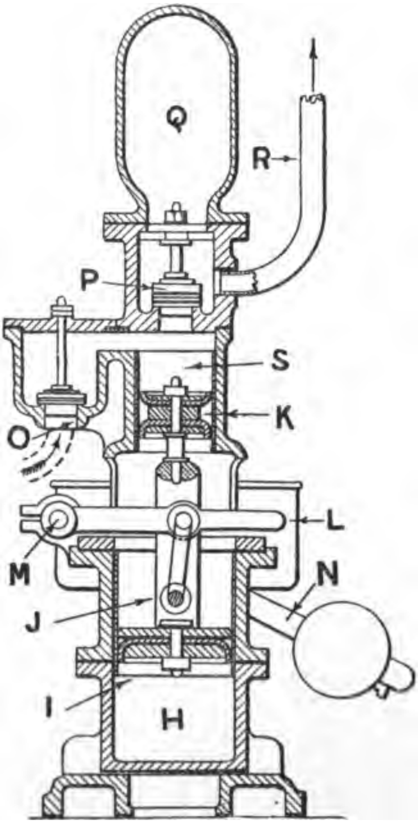

FIG. 35.

Fig. 20. In Fig. 35, H is the body-pipe filled with impure water, which is subjected to shock by the closing of the dash-valve as in an ordinary ram. I is a piston sliding in a cylinder, and J is a connecting link to a smaller piston, K. The pistons are pushed down by the arm, L, which is hinged at M. On the same axle are two weighted levers, N (one only can be shown in the section). O is a sucker-valve over an opening to which the suction-pipe is attached, P is the delivery-valve in the air vessel, Q, and R is the delivery-pipe leading to the storage tank.

The ram works as follows:—As soon as the working-valve is dashed on to its seating, the water in H is compressed sufficiently to raise the pistons, I and K, and also the weighted levers, N. On rising, the piston K pushes the water out of S through the delivery-valve P, into the air-vessel, and thence through the pipe R. As soon as the shock of the drive-water is overcome, the weighted lever N actuates lever L, and presses the two pistons I and K down to their original positions, leaving a vacuum at S, which is again filled with water through the sucker-valve and pipe at O.

With this appliance the waters cannot mix, nor the clean or pure water be contaminated by that which works the ram.

In the two foregoing appliances the pump pistons or plungers had their direction of travel reversed, to form a vacuum in the suction chambers, by means of springs or weighted levers. Efforts have been made to obtain the same results by the pressure of water, and Fig. 36 is a section of a patented appliance for that purpose.

In the drawing, T is the drive-pipe, supplied

with foul water for working the ram; U is the dash-valve over the body-pipe V; W is a piston with a connecting rod, X, to a second piston, Y. This latter is hollow, with a plunger, Z, inside. The hollow piston works in the larger cylinder, which may be termed the 'barrel,' and the plunger in a smaller cylinder, A, as shown in the figure.

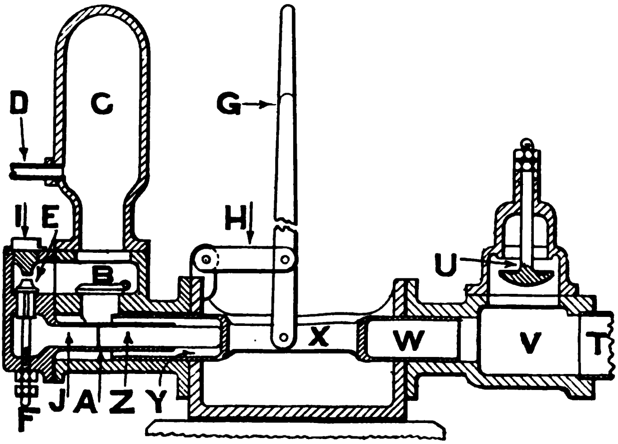

FIG. 36.

A sucker-valve and pipe are attached to the larger cylinder, but are not shown in the figure. At B is the delivery-valve opening into the air-chamber C, and D is the delivery-pipe. At E is a small valve which is kept partially open by means of the screwed spindle, F, beneath it. When the ram is working, a portion of the water is forced through this valve in addition to that which is forced through the proper delivery-valve, B. But because

the valve, E, does not quite close, a small quantity of water returns through it and pushes back the hollow pistons which are coupled together by the connecting rod, X. G is a lever with connecting link, H, for working the ram until sufficient water has been raised to form a head for pushing back the plunger, Z, or for working the ram by hand in cases of emergency, such as during the failure of the working supply.

The action is as follows:—The driving water acts upon the dash-valve, U, in the same manner as with ordinary rams, and the shock drives the piston W, which pushes the piston Y, and forces clean water through B. The piston slides past the opening, and gradually closes the orifice under the valve B, thus minimising shock in the body-pipe.

As soon as the force of the driving water is expended, a portion returns through the small valve E into J, and pushes the pistons back into their original positions. The force of this back-pressure is equal to the head of water in the delivery-pipe acting upon the end of the solid piston Z.

In a modification of the same patent the opening or passage between the valves B and E is omitted, and a pipe substituted for the plug I. The pipe is continued upwards and connected to a small tank fixed at the necessary height for giving sufficient head for pushing back the pistons. In this arrangement the same back-pressure water is constantly re-used, and simply rises and falls in the pipe leading to the tank at each to-and-fro movement of the pistons. With this appliance there may be said to be three water-supplies—namely, that which drives the pistons forward, that which

pushes them back, and that which is pumped. The back-pressure tank can be filled by hand or any other means, and, as there is no waste of the water, would require very little attention.

All the pumping rams that have been described are limited in the depth from which they will raise water, in the same manner as any other kind of pumps, the limit being as was given when describing Fig. 33.

CHAPTER XVII

AUTOMATIC FEED TO HYDRAULIC RAMS

IN many places the water-supply is very limited, and not sufficient for continuously working a ram. Or the supply may be plentiful during certain seasons and become reduced in other seasons which are drier. This is especially the case when the rams are fed from intermittent springs, or when the water has to be collected from a catching area similar to that shown by Fig. 8.

In such cases the feed-water tank or reservoir, where possible, has to be of a good size for storing the supply when plentiful. But there are many places where this is impracticable, or where the water could not be stored at a sufficient height for giving the necessary head.

Where the ram is 'close at home,' so that it can be frequently visited, the valve shown in Fig. 7 can be dropped by hand when the supply is exhausted, and again opened when the tank has re-filled.

But when the tank is a mile or two away from the house such attention cannot very well be given, and it then becomes necessary to fix an automatic-acting arrangement for closing the valve when the supply fails to yield sufficient for working the ram, and for re-opening it when the water has again accumulated.

Fig. 37 is a sketch section of a primitive appliance the writer once saw, and which was found to be answering fairly satisfactorily, although some of the water was wasted. In the sketch, K was a brick-built tank, filled from small springs in a wood, L a drop-valve with a chain to the hinged lever, M. On the outer end of the lever a bucket, N, was suspended, and this was filled through the pipe O when the tank overflowed. The full bucket was heavy enough to pull down the lever and open the valve.

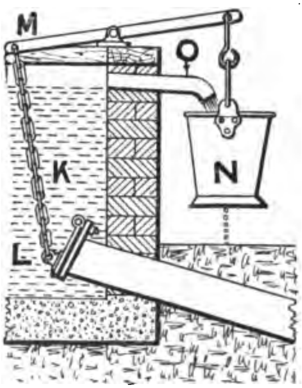

FIG. 37.

The bucket had a small hole in the bottom so that, when the tank ceased to overflow, it gradually emptied, allowing the valve to close, and thus stopping the ram from working. When the tank again overflowed and filled the bucket, the valve was again opened and the ram re-started.

On studying the arrangement it will be noticed that so long as the supply is plentiful the ram will work, but will stop when the tank ceases to overflow.

Without it the dribble into the tank during a dry season would flow away through the ram, because the force would not be sufficient to close the dash-valve, and the water would be wasted. But with it a small portion of water is raised by

the ram, and that is far better than having none at all.

A better appliance than the bucket with the hole in the bottom would be to suspend a properly-constructed rectangular vessel, with guides to keep it steady, and a siphon-pipe arranged for automatically emptying the contents back into the feed-tank when the water in the latter had lowered to a certain level. This would save a few gallons from being wasted each time the supply ran short, and also enable the counterpoise to act more quickly. Neither would any of the water be running to waste when the counterpoise tank was filling.

Fig. 38 is a sectional drawing showing the arrangement, in which P is the small siphon for emptying the counterpoise-tank when the water in the drive-tank fell below a certain level.

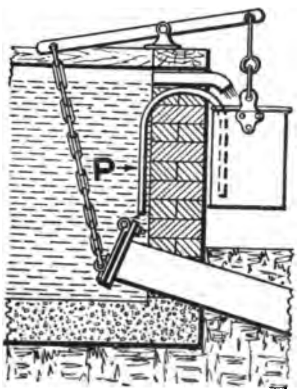

FIG. 38.

It should be mentioned that Figs. 37 and 38 are only diagrammatic, and are not intended to show perfect appliances. Those readers who have thoroughly grasped the principles which actuate hydraulic rams will no doubt notice that the flap-valve on the inlet end of the drive-pipe in each case will act in a manner similar to the dash-valve of the ram, especially in cases where the loads

on the ends of the hinged levers are equal or nearly balance each other. There is also the difficulty of opening the flap-valve when the pipe leading to the ram is filled with water. To open the valve, a

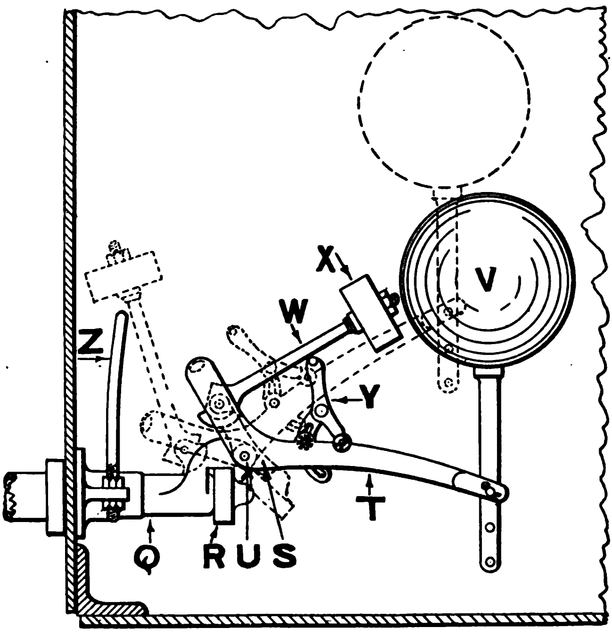

FIG. 39.

slow, steady pull is not nearly so good as a sudden jerk on the chain.

A much better arrangement than either of those illustrated by Figs. 37 and 38 is the patented appliance shown by Fig. 39. In the drawing, Q is the

body fixed on the end of the drive-pipe in the feed-tank, R is a valve fixed on the lever S, which is attached to another lever, T, and which is hinged at U. At the end of the latter lever is a copper ball, V, with a stem pinned to the lever T, and which can be adjusted to any desired length. The left-hand end of T is cranked, and to it is attached a spindle, W, with a weight, X ; Y is a jointed stud hinged to T, with a slotted cam arm and adjusting screw. A small roller on the top of Y supports the weighted spindle W, and Z is a rest for the latter when the valve is open.

The action is as follows :—Assuming the details to be in the positions shown, the valve R is shut and no water can flow down the drive-pipe Q, the tank being nearly empty. As the tank fills, the ball V rises to the position shown by dotted lines, and raises the lever T with the attachment Y. This presses against W, and pushes it upwards until the whole is sufficiently high for the weight X to be beyond the centre of gravity, and it falls against the rest bar, Z. This part of the motion is so sudden that the valve R is quickly opened, the force being sufficient to overcome not only the outside pressure of water against the valve, but also the weight of that inside the pipe.

When the tank is filled and contains sufficient water to work the ram, the whole of the arrangements are as shown by dotted lines ; but if the supply fails, the float V lowers and actuates the various levers until the weight X is on the reverse side of the centre of gravity, when it falls forward and closes the valve R, as shown by firm lines.

There is no doubt that this is a valuable appliance for using where the supply to a ram is meagre

or intermittent, because by its use not a drop of water need be wasted.

RAM-PITS AND RAM-HOUSES

Hydraulic rams are almost invariably fixed at some distance from the dwelling, sometimes a mile or two away; and it therefore follows that they should be protected not only from frost, but also from injury by cattle, or by men or boys led by curiosity to tamper with them.

The best position is in an underground chamber. When the pit is very deep the entry should be through a trap-door in a frame at, or a few inches above, ground-level. An iron ladder or step-irons, either of which occupies but little room, should be built in the wall for getting down to the ram.

When the ram-pit is near to the surface of the ground the entrance can be by means of outside steps, built at the same time as the ram-house. A door should be hung to open inwards, and a drain made for taking away rainwater from the bottom landing.

In some cases it is necessary to fix wood flaps over the stairs or steps, or a railing, for preventing cattle falling down. The former is the better plan, as in the winter time, should the ram require attention, it is easier to clear the snow off the covers than to dig it out from the sunken steps. Underground pits are best built circular in plan, and with domed brickwork or stone roofs. The diameter should be from 4 ft. to 6 ft., according to the size of the ram, or if duplicate rams are fixed;

the height should not be less than 6 ft. if possible to get it.

When the ram can be fixed above ground a house about 8 ft. by 5 ft. inside measurement is a convenient size. Such houses have to be roofed, and plain tiles or stone shingles are good for the purpose. In a house of this kind with which the writer had to deal, the roof was boarded, then felted and battened before tiling, for keeping out frost. Openings were left in the gable ends for ventilation, but these apertures were afterwards blocked up for keeping out birds, with the result that in about three years the rafters and boarding began to rot. The reek or vapour from the water could not escape, with the result as stated.

Incidentally it may be mentioned that the water to hydraulic rams very rarely freezes so long as the rams are working. Even during the coldest weather it is not necessary to stop up all ventilation in an above-ground house. It is however advisable to have all openings situated above the level of the ram, so that a sharp current of cold air cannot impinge against it.

The entrances to ram-houses of any kind should be locked, and for this brass padlocks or oak rim locks are the best.

As the greatest force of the water shock occurs near the ram, it is important that the latter should be well fixed, either to an oak base secured with concrete, or to a stone or concrete floor. The force of the drive-water has a tendency to push the ram from the drive-pipe, and by firmly fixing the ram an opposing force is offered. Under great heads the leaded joint to the body-pipe is sometimes

blown, and the flanged connections to the ram or stop-valve are broken.

All ram-houses should be paved and drained, and provision made for the tail-water to flow freely away. Although some rams will work when flooded, or with the dash-valve under water, they will do so much better when there is no back-water to interfere with their action.

CHAPTER XVIII

MAKING REPAIRS TO HYDRAULIC RAMS

ALL rams are manufactured by specialists, and it is very difficult for plumbers properly to repair them unless they have the proper fittings. Many rams at work have been repaired and parts replaced with totally unsuitable pieces. Such rams are always in trouble, and the cost of frequent repairs is a permanent tax on their owners. In one instance the writer saw no fewer than nine old iron dash-valves outside a ram-house. Their number and variation in size and weight was proof that the ram had been a considerable source of trouble.

When ordering a new ram the working parts or valves should be in duplicate, so that when one is much worn or breaks down it can be exchanged in a very short time. The broken or defective valve should be sent to the makers and repaired or renewed if necessary, ready for refixing when occasion requires. Not only would this lead to a saving in the cost of repairs, but the plumber who has to do the work would give more satisfaction to his client, and the reputation of the ram-maker would not be injured. It may be added that these remarks apply to all kinds of special fittings used by plumbers.

Country, and especially estate, plumbers have advantages over those who work in large towns, in that they frequently have a great deal to do with rams. There is many a ram fixed which may be said to have a 'temper of its own,' and the plumber who is usually called in to adjust or repair it can often succeed much better than a stranger would in making it work properly.

If all rams were exactly alike and worked under similar conditions, rules could be formulated for their repairing, adjusting, or regulating. But as the conditions vary both with regard to size of ram, quantity and head of drive-water, length and size of drive and delivery pipes, and the quantity and height delivered, it follows that each ram has to be studied under its own especial conditions. There are a few empirical rules, or those based on practical experience, but they are only suitable for conditions which are exactly similar in all details to those from which they were deduced. At the same time they form a basis for making calculations which, if not exactly, are approximately correct.

The rules given in preceding Chapters are those which should be followed when fixing new rams. The same rules will also be of great help to those who have to repair, or otherwise deal with, rams that are erratic in their action. By the assistance of such rules the workman is the better able to judge if the ram was fixed properly in the first instance. It is often far better to entirely refix or alter a ram that is improperly fixed than it is to keep making useless trial alterations and repairs which have no finality.

Causes of Rams Stopping Working

Sometimes a machine will work satisfactorily for a time and then stop, there being some difficulty in finding the reason. In a few such cases experiment will often succeed when theory fails. But it must be admitted that the plumber who knows the theory will be better able to make the right experiment than the one who is ignorant of the principles upon which the working of rams is based.

One great cause of rams stopping working, after being in use for some time, is the reduction in area, and roughness inside, of the drive-pipe, caused by rusting. Another cause is the use of galvanised-iron drive-pipes. Such pipes are usually very rough inside, and also have exposed threads and enlargements of the water-way inside the screwed sockets. The head of water may be sufficient for dashing the valve on to its seating, but the force of the reflow is so small, by reason of excessive friction in the drive-pipe, that the valve will not open properly for the next stroke to be efficient. In some such cases the valve will, at times, be found to chatter; and a ram with a chattering dash-valve is always uncertain in its action and liable to stop.

The writer once found the drive-pipe to be lined inside with a kind of slime, and this was traced to ducks being kept in the small lake which supplied the ram. On passing a small bundle of fine wire netting through the pipe, the slime was removed and the ram then worked properly.

If the drive-pipe leaks, the water will not reflow sufficiently to open the dash-valve and the ram will cease working.

Air in the drive-pipe has an injurious effect. 'Clear' or 'straight-way' valves should always be used, as has been before explained. Ordinary stop-valves with a circuitous water-way through them should never be used, because of the excessive friction of the water in turning the sharp elbows, and also because a small quantity of air is frequently pent up inside and cannot escape.

The extra friction of the water when passing through a bend, especially when fixed near the ram, will sometimes affect the reflux action of the water and cause the dash-valve to hang up.

Some of the patented rams will work with either long or short strokes, and will adjust themselves to the work they are doing. But those of ordinary make have to be regulated by washers or screws, according to the lengths of the drive-pipes and the heads of water above the rams. In such cases the length of stroke should be so regulated as to be as long as possible. A ram with a short stroke is more liable to stop than one which has a long stroke.

When an air-vessel is water-logged the resistance is so great that the delivery-valve will not open. This will sometimes stop the ram, owing to an insufficient reflux movement of the drive-water.

In one instance the height to which the water was delivered was so low, and the air-pressure inside the vessel so small, that when the shock of the dash-valve took place water was pushed through the delivery-valve for a second or two afterwards. This resulted in the momentum of the drive-water being slowly arrested, and there was no reflow inside the drive-pipe. By constantly pushing the dash-valve down by hand, a considerable

quantity of water was raised, but when left to work by itself the ram immediately stopped.

A case almost similar to the latter, in a Midland county, was for a time a considerable cause of

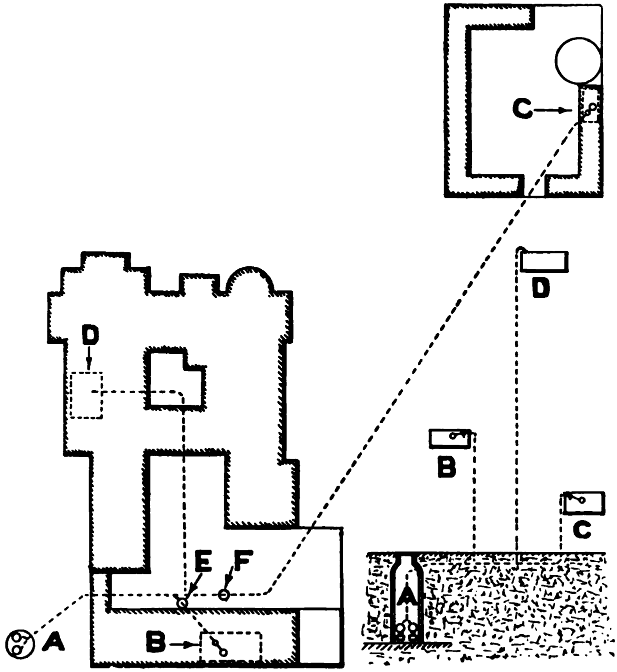

FIG. 40. FIG. 41.

anxiety. Two rams were fixed in a pit about 15 ft. below ground level, in the position shown at A, Fig. 40. At B, C, and D were cisterns averaging about 1,000 gals. each, fixed in brewhouse, stables,

and mansion at heights of about 35 ft., 25 ft., and 65 ft. respectively above the ram. The cistern C in the stables was about 100 yards distant. Fig. 41 is a diagrammatic sketch, drawn to scale, to show the relative heights of the various tanks above the rams. The tanks are marked to correspond with those shown in Fig. 40. The water-supply was only sufficient for working one ram at a time, the other being held in reserve in case of a breakdown. Both rams were connected to the same rising main, but had separate drive-pipes. Ball-valves were fixed to B and C, but the pipe to D had an open end.

Each ram could be regulated to raise water to either cistern separately, but not to fill all of them in succession. When adjusted for filling the highest cistern, the ram immediately stopped when water ran into the lowest cistern, and *vice versâ.*

Experiment having failed to solve the problem, it was decided to calculate the flow-energy exerted on the ram and compare it with the work done in raising water to each cistern respectively, and the result showed a wide difference.

As the rams would do what was required to each cistern separately, it was considered that neither they nor their drive-pipes need be altered, and the trouble could be overcome by making the work of raising the water uniform to each cistern.

With this object, square-headed stop-cocks were fixed at E and F, and closed until the resistance, as shown by a pressure-gauge, was found to be equal to each cistern. The rams then worked satisfactorily, and there was the further advantage that D always had water running into it, and did not have to wait for its supply until the lower

cisterns were filled. But when the latter were filled and the ball-cocks were closed a stronger stream went up to D.

It may be added that ordinary stop-valves were fixed in the delivery-pipes to shut off the supply to the cisterns when necessary to do so, and instructions were given that the other, or regulating cocks, were never to be turned or interfered with in any way.

Another cause of rams stopping working is a variation in the head of the drive-water, and this is very common where the rams are supplied by intermittent springs. Or the supply may be so lowered that the inlet-end of the drive-pipe is exposed and air is carried in with the water. In such cases the dash-valves will sometimes chatter for a few seconds and eventually remain closed; or if the dash-valve is a very heavy one it will remain open.

When the leaded joints in a cast-iron drive-pipe 'blow,' it is a difficult matter to make them sound. In some cases it is a real economy to go to some trouble and melt out the old lead and remake the joints, using rod lead instead of ordinary yarn. When remaking the joints, two or three cold lead rings or bands should be well caulked in, and the sockets then filled with molten lead. The lead should be poured as cool as possible, so as not to shrink much on further cooling, and then be staved in the usual manner. For new cast-iron drive-pipes the sockets should always have grooves inside, as shown at H, Fig. 11. When remaking the joints on old cast-iron drive-pipes, the socket and spicket ends can be made red-hot to burn off anything which would prevent them

rusting, and the joints then made with the rust cement which has been described.

VARYING HEIGHTS OF DELIVERY FORM A RAM

The question is sometimes raised as to whether a hydraulic ram can be used to raise water to two or more farmsteads situated at different levels and in different directions from the ram. As was explained when dealing with the case shown by Figs. 40 and 41, this can be done, but especial precautions must be taken to ensure that the load on, or the work done by, the ram is not varied in any way. The chief reason is the impossibility of altering the length of the drive-pipe to suit the different heights to which the water is sent by the ram.

The same remarks apply to a case where a ram was fixed to supply a small cistern in each of several labourers' cottages. These cottages were all situated at different levels.

The question has also been raised as to whether a hydraulic ram can be used to supply a fountain fixed in a large basin.

In such problems as the above it is possible to attain success, but such success cannot be maintained for any length of time. In addition to the subtle changes that take place in hydraulic rams and their connections, variations in the temperature of the water, and in the temperature and pressure of the atmosphere, all have an influence on the working of a hydraulic ram, especially when it will work only if adjusted to a nicety. The author has been struck with the variations in the results

obtained on different days when experimenting with the ram shown by Fig. 14.

For the foregoing reasons it is always advisable for a ram to send the water into an elevated tank or reservoir from which service-pipes can be laid to supply buildings situated in different directions. The same applies to the working of a fountain. In the latter case it is obvious that the fountain would not be required to play in the winter-time, and during other seasons the ram would have to be stopped from working when the fountain was not desired to play. The ram should send the water to an elevated tank. A tub or a barrel on the top of a post, and an overflow-pipe to the fountain basin, would answer as well as a more costly installation.

With regard to the noises made by hydraulic rams being heard in a house where the storage tank is situated inside, it is impossible to prevent the sound being conducted by the delivery-pipe and the contained water. Those rams, however, which have rubber or leather washers on the dash-valve are not quite so noisy as are those which have metal valves and metal seatings.

CONCLUSION

There are many peculiarities attached to the working of hydraulic rams, and it is almost impossible to describe them all. The theory of their working may be clearly understood, but there are so many variations in their fitting up and the work extracted from them that theory may sometimes appear to be at fault. But upon consideration it

is obvious that the difference arises from the difficulty in obtaining all the necessary facts upon which to base it, rather than that theory itself is wrong.

That hydraulic rams are valuable appliances, and under favourable conditions the most economical that can be used for raising moderate quantities of water to moderate heights, is evidenced by the number that are giving satisfactory results in various parts of the country.

That those who have to fit up or repair hydraulic rams may have at least an elementary knowledge of their action and working is the object and aim of the writer in publishing this little book.

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